Irondequoit Bay Slope Vegetation Management Plan

For the

Town of Irondequoit
1280 Titus Avenue,
Rochester, NY 14617

Final Report

May 2008

URBAN FORESTRY LLC

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1280 Titus Avenue,
Rochester, NY 14617
Contact:
Mr. Marty Piecuch
Commissioner of Public Works

Final Report

By

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Executive Summary

This plan was developed to assist the Town of Irondequoit in the management of vegetation on the steep slopes bordering the Irondequoit Bay. The need for this plan was identified because several large scale slope failures had occurred in the immediate past in areas where vegetation had been disturbed. Questions arose during mitigation efforts as to the contribution vegetation removal was making to slope instability and how to best utilize vegetation to manage existing failures and prevent future slope failure issues.

The plan is presented in accordance with the three main tasks of the project funded by the Lake Ontario Coastal Initiative. Task 1 was a review of literature pertinent to current slope and vegetation management practices being employed on the Great Lakes and other similar ecosystems. Task 2 was the field survey of the slopes to classify their stability, vegetation characteristics, and to determine their current management needs. Task 3 was to develop this vegetation management plan based on the information collected in the literature review and field survey.

The slope and vegetation survey were completed in September of 2007 by identifying each slope on a series of aerial photographs. All of the slopes were surveyed and divided into 39 distinct forest stands based on the vegetation within each stand. Of the 39 stands, forty-six percent (46%) were classified as containing primarily native trees, 44% were classified as mixed native and invasive species, and 10% were classified as invasive trees. Common native tree species included white, red and black oak, hickory, sugar and red maple, ash, beech, cottonwood or poplar, tulip poplar, sassafras, hawthorn and ironwood. The most common non-native invasive species were Norway maple and ailanthus.

In general, the native stands exhibited much greater diversity in terms of numbers and types of species, and in stand structure. In particular, native stands contained much higher numbers of over story trees, shrubs and groundcover plants versus the mixed or invasive stands.

Twenty-eight or 73% of the stands have some type of disturbance. In 18 of those stands with disturbance, cutting and clearing of vegetation was the most common type of perturbation. Other types of disturbance identified included building construction, previous unknown disturbance, filling, and roadway cuts.

The survey identified five slopes that have failed and one that was in failure. They were further classified by the type failure and the percent of the stand that has failed or is in failure. These failures should be evaluated by the Town to determine if engineering treatments are required.

The literature review clearly identified that vegetation has a positive influence on slope stability through several well documented mechanisms. The field survey

showed that stands of native vegetation have characteristics that would contribute to increased slope stability including greater size class distribution, greater shrub and ground cover, and a larger number of mature, over story trees. The use of native tree species to re-vegetate slopes is a solid recommendation that can be made from this project.

Prevention of disturbances is the most effective solution to preserving the native plant communities and helping maintain the stability of the slopes. The field survey revealed there are various activities that are being completed by property owners including tree pruning and clearing, and dumping that are having an adverse impact on the slope vegetation. Some of this work is being completed by for hire tree and landscape companies. Enhancing the Town Code to restrict the activities of property owners and tree and landscape service providers is an option for helping preservation of the slopes.

The following are general strategies recommended for management of vegetation to enhance slope stability based on the field survey and literature review. There are four management goals that should guide the Town in these efforts:

1. Minimize the disturbance of native stands on these critical slopes.
    a. Site Development
    b. Vegetation Removal
    c. Tree Pruning
2. Promote the removal of existing non-native plant species already established in most stands and planting of native plant species
3. Promote the removal of non-native plant species and planting of native plant species in yards adjacent to the slopes
4. Manage to preserve and enhance the native vegetation on these slopes at the stand structure level.
    - Overstory – Large and mature trees
    - Intermediate – Intermediate sized and maturing
    - Saplings – Young and small sized trees
    - Shrubs
    - Goundcover

Specific recommendations on the application of these management practices are presented for each slope and vegetation type along the Irondequoit Bay.

While the information in this plan solidly documents the importance of vegetation to slope failures, it is also clear that managing vegetation can only be one component of the Town's slope management plan. Slopes, as with most ecological systems, are composed of inherently interconnected components. The Town clearly needs to comprehensively address all the factors affecting failure slope management to be successful. Similarly, remediation of existing slope failures will likely require a multi-faceted approach that includes engineering and vegetation aspects.

Introduction

This plan was developed to assist the Town of Irondequoit in the management of vegetation on the steep slopes bordering the Irondequoit Bay. The need for this plan was identified because several large scale slope failures had occurred in the immediate past in areas where vegetation had been disturbed. Questions arose during mitigation efforts as to the contribution vegetation removal was making to slope instability and how to best utilize vegetation to manage existing failures and prevent future failures.

Slope failure represents the mass movement of soil and vegetation down a slope, and maybe commonly referred to as landslides. The failures represent a significant threat to the stability of homes and property at both the top and bottoms of the slopes, and may also impact water quality in the Irondequoit Bay. An example of the potential for slope failures to impact homes and water occurred at German Village in 2004.

Although slope failures are part of a natural process, the failures along the Bay appear to have resulted mainly from man's activities on and near the slopes. These include cutting of trees and other vegetation, affecting surface and groundwater amounts and patterns, and removal and disturbance of soils on the slopes.

While the information in this plan solidly documents the importance of vegetation to slope failures, it is also clear that managing vegetation can only be one component of the Town's slope management plan. Slopes, as with most ecological systems, are composed of inherently interconnected components. The Town clearly needs to comprehensively address all the factors affecting failure slope management to be successful. Similarly, remediation of existing slope failures will likely require a multi-faceted approach that includes engineering and vegetation components.

However, this management plan will only address the effects of vegetation on slope failures. The plan is presented in accordance with the three main tasks of the project funded by the Lake Ontario Coastal Initiative. Task 1 was a review of prevalent literature pertinent to current slope and vegetation management practices being employed on the Great Lakes and other similar ecosystems. Task 2 was the field survey of the slopes to classify their stability, vegetation characteristics, and to determine their current management needs. Task 3 was to develop this vegetation management plan based on the information collected in the literature review and field survey.

The final section of this plan will combine the above resources and results to offer a series of management strategies and recommendations for slope along the Bay. It will also present general vegetation management strategies that could assist the Town in providing guidance to citizens that live along the Bay.

Slope Vegetation Survey Methodology

Objectives

It is impossible to effectively and efficiently manage the vegetation of these slopes without an accurate assessment of the vegetation on the slopes. The objective of the slope vegetation survey was to inventory the vegetation and physical characteristics of the slopes in order to provide the information necessary to develop management strategies to address deficiencies found in the survey.

The vegetation survey was developed and completed in two phases. The first phase was exploratory and because of the steepness of some slopes was completed by boat with the objective of designing the on ground survey methodology of the second phase. In April 2007, a general survey of slopes was made by motorized boat to identify broad vegetation types, and target areas for further inspection. These areas where noted on USGS topographical maps. In July, a second survey by canoe was made to further inspect slopes for failures, delineate vegetation types and forest stands, and identify potential management issues.

Methods

Based on the information retained in these preliminary surveys, and the literature review completed in Task 1, the on ground survey methodology was designed and the survey was competed in September 2007. The survey was based on identification of similar forest stand types rather than individual slopes. However, slope characteristics were considered as a secondary classification factor.

The entire length of the Bay slopes was surveyed by walking from south to north and data was collected regarding physical features of the slopes and vegetation. Aerial photographs of the west slope of the bay were retained from GoogleMaps.com and divided into nine “Slope Maps”. On each map, the vegetation was divided into forest stand type and numbered with “Stand #” (See Appendix 1 for the individual maps).

Data Collected

Within each stand the following information was collected.

Slope Map # and Stand # - the slope map# and corresponding stand # within the slope map.
Slope % - the slopes within the stand were measured with a clinometer and the high and low percentage observed were noted
Disturbance – Types of disturbance observed within the stand were recorded including vegetation cutting, clearing, pruning, construction or dumping.
Slope Stability – an observation of the stability of the slope was made and classified as stable, failing or failed.

% in failure – if the slope was in failure or had failed and visual estimate of the area of the stand that was in failure or and failed was noted.
Type of Failure – the type of failure if present as defined in the literature review.
Impact of Failure – the potential targets of a slope failure including; house, road or none.
Stand Type – a visual classification of the majority of plant species present within the stand

> Native – the plants observed are almost exclusively native plant species
> Mixed – the plants observed are approximately equal in number including native and non-native or invasive plant species
> Invasive – the plant species observed are predominately non-native or invasive plant species.

Cover % - an observed percentage of the stand area that is covered with vegetation
Invasive % - an observed percentage of the stand that is comprised of non-native or invasive plant species
Overstory % - an observed percentage of the trees in the stand that include overstory trees. This includes trees that are large and mature in age. Species of overstory trees observed was noted.
Intermediate % - an observed percentage of the trees that are intermediate in age or size. Species of intermediate tree species of trees observed was noted.
Saplings % - an observed percentage of the trees that are young saplings or small trees. Species of sapling trees observed was noted.
Shrub Layer % Cover – a visual estimate of the percentage of the stand area that is covered with shrub species. Shrub species observed were noted.
Ground Cover % - a visual estimate of the percentage of the stand area that is cover with groundcover plants. Species of ground cover observed were noted.
Management Recommendation – based on the observations made of the stand recommendations regarding managing the vegetation and disturbances observed

Summary of Survey Results

Slope Steepness

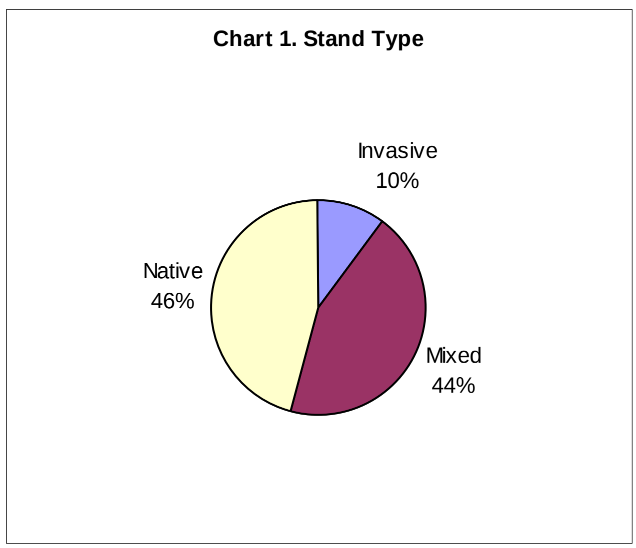
The Town of Irondequoit code defines a steep slope as one with a 15% or greater slope. Steep slopes were identified on Slope Maps 2 thru 9 and none on the south end of the bay on Slope Map 1. Steepness ranged from 15 to 45 percent on slopes classified as steep.

Map #	# of Stands	Slope % Range
1	1	No steep slopes
2	7	25-40
3	6	25-40
4	2	30-35
5	8	25-35
6	4	20-40
7	3	20-30
8	2	15-30
9	7	20-45

Table 1. The number of stands of vegetation and slopes by slope map number as identified in the field survey.

Stand Type & Composition

Chart 1. Forest stand classifications made during the field survey.



A total of 39 distinctive vegetation stands were identified (Table 1 and Appendix 1). Forty-six percent (46%) of the stands were classified as native, 44% were categorized as mixed native and invasive, and 10% were classified as primarily being comprised of invasive species (Chart 1).

Slope Map 5 has the highest number of distinctive forest stands and Slope Maps 4 and 8 have the least.

The species of vegetation observed in the survey can be found in Appendix 3. Common native tree species included white, red and black oak, hickory, sugar and red maple, ash, beech, poplar, tulip poplar, sassafras, hawthorn and ironwood. The most common non-native species were Norway maple and ailanthus.

The survey visually identified the approximate percentage of overstory trees, intermediate trees, sapling trees, and shrubs and groundcover present in each of the native, mixed and invasive stands (Table 2). It also included identifying the species of plants within these classifications (Appendix 3).

	Overstory %	Intermediate %	Sapling %	Shrub %	Ground Cover %
Native	20	47	25	5	16
Mixed	15	53	32	2	8
Invasive	4	56	39	1	1

Table 2. The vegetation type by forest stand classification made in the field survey.

In the native stands, there is a more even distribution of the number of plants across the stand structure and in particular the much higher numbers of overstory trees, shrubs and groundcover plants compared to the mixed or invasive stands.

Slope Failures and Disturbance

Disturbance was classified in the survey a number of ways. The first and of most concern was the identification of slope failures. The survey identified five slopes that have failed and one that was in failure (Table 3). They were further classified by the type failure and the percent of the stand that has failed or is in failure. These failures should be evaluated by the Town to determine if engineering treatments are required.

Stand #	Type of Failure	% Slope Affected	Stand Type	% Invasive	Notes
2-2	Slump	25	Invasive	95	75% of failure moving
3-1	Slide/slump	60	Mixed	50	Ground water seepage, Invasives dominate disturbed areas
3-5	Windthrow	10	Native	15	Tree windthrow on south edge
5-4	Slide	50	Invasive	95	Failure on the south edge
8-2	Fall	1	Native	1	Failure on island edge
9-6	Leaning Trees		Mixed	50	Slope on edge of bay disturbed, native above

Table 3. Slope failures identified in the field survey. The failures on Stands 3-1 & 3-5 are characterized as natural while the remaining three were related to disturbances.

Twenty-eight or 73% of the stands have some type of disturbance (Chart 2). In eighteen of those stands with disturbance, cutting and clearing of vegetation was

the most common type of disturbance. Other types of disturbance identified included building construction, previous unknown disturbance, filling, and roadway cuts. Only five of the 39 stands did not have residences adjacent to the stands and only 3 of the stands would not impact man-made structures if there was a catastrophic slope failure.

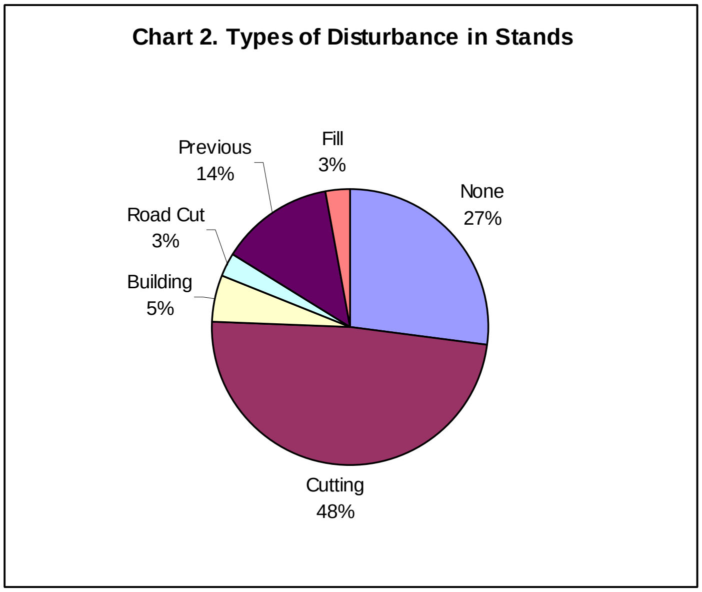


Chart 2. Disturbance type identified in the field survey.

Discussion and Management Implications

The field survey showed that nearly 60% of the forest the stands along the bay had an appreciable component of non-native species (Chart 1). Given that most non-native trees such as Norway maple and ailanthus usually become established in native forests after a disturbance, this indicates that the slopes along the bay have been subjected to a high level of disturbance in the past. Further, 10% of the stands were primarily comprised of pure stands of non-native trees, indicating that the some disturbances were significant enough to allow conversion almost completely to these species.

Evaluation of individual stands showed that native stands had a better distribution of tree size classes, from over story trees through shrubs, and had higher ground cover than non-native stands (Table 2). Stands with non-native trees were composed of mostly intermediate and sapling trees with few over story trees, shrubs or ground cover. This tendency towards even aged stands with few over story trees also suggests that the invasive stands become established at a single time following a disturbance.

Photo 1. A native stand with large mature oak trees and plentiful understory vegetation.

The lack of shrubs and ground cover in non-native stands is likely due to the intense shading associated with Norway maple and dense stands formed by ailanthus and Norway maple. This absence of shrubs and ground cover may

contribute to surface erosion and soil movement in these stands, particularly after high rainfall events. For example, grasses and herbaceous plants are well known in preventing surface erosion and have been used extensively for this purpose (Gray and Leister, 1989; Bache and MacAskill, 1984; Sotir and Gray; 1996; Schiechtle, H. M. 1985).

Photo 2. An intermediate stand of Norway maple. Note that there is no shrub or groundcover layer due to the dense shading.

Non-native stands also usually lacked over story species that are important in anchoring soil and removing soil moisture deep within the soil profile. In fact, variation in the age and species of forest vegetation can also affect the local stability of forest slopes, with mature forest providing more root stabilization then planted (even-aged) forests (Schmidt et. al., 2001). Deep-rooted species with vertical and tap roots are most effective for stabilizing and resisting sliding on slopes (Gray and Leister, 1989; Gray and Megahan, 1981). Woody-deep rooted trees and shrubs are the best vegetation to provide slope stability, and removal of vegetation from forested slopes increase landslides (Dhakal and Sidle, 2003; others). Clearly, native stands containing deep-rooted oaks, hickories, sugar maples and other trees that are large at maturity would provide the most benefit to slope stability. Conversely, stands of non-native Norway maple and ailanthus have characteristics that are less desirable for soil and slope stability.

Photo 3. An exposed tap root of a white oak on a washed out bank.

Native stands also exhibited substantial species diversity. This diversity is to some degree a reflection of different soil types on the slopes as well as slope aspect (direction). The diversity allows a large potential list of species that could be planted on the slopes. Based on the literature, establishing and maintaining

native plant communities appears to be an important objective. Native vegetation is often an excellent indicator of the types of plant communities that will ultimately prevail on a site and creation of self sustaining communities is an important ecological goal (Bache and MacAskill, 1984).

Many of the native species produce fruit or nuts that are spread by birds or other animals, and some such as maple and ash produce wind-spread seed. The use these species at the top of slopes has potential to provide a seed source for dispersal down the slopes. Some of the species that are small in size at maturity, such as hawthorn, shadbush, and hophornbeam, could be planted near houses with less concern for blocking views or vistas.

Conversely, the presences of non-native plant species in yards along the tops of slopes provides a constant seed source for spreading into native stands or after stands are disturbed. Species such as Norway maple, ailanthus, sycamore maple, and short-lived native species such as cottonwood, all produce copious amounts of wind dispersed seeds. Their planting should be discouraged if possible, and removal or significant pruning of these species should be encouraged.

One of the most significant findings of the survey is that that over 40% of the stands were classified as mixed native and non-native invasive species. These stands would likely be converted to non-native species if disturbance occurs because of the high reproductive potential of Norway maple and ailanthus and their ability to rapidly produce dense shade and exclude other vegetation. However, elimination of non-native invasive species from these stands seems impractical. Therefore, avoiding disturbances to the degree possible seems to be the most reasonable management option where these mixed stands are present.

Photo 4. Mixed stand of native and non-native plant species. Disturbance of these stands will likely convert them to mostly non-native species.

There were a limited number of failures on the bay slopes to make conclusive judgment of the impact of native versus non-native tree species on slope failures. However, native species were associated with only two failures that were limited in extent and could be considered “natural” events. These failures were windthrow of mature trees and a fall along the shore of the bay.

Photo 5. Invasive Norway maple stand with virtually no understory vegetation. The slope is moving downward as indicated by the curve in the tree trunk. The slope moves, the tree leans and then self -corrects to grow to the light source in the top of the canopy.

Catastrophic slope failures were in all cases associated with forest stands that were disturbed by man and contained invasive species. The invasive species establish quickly after a disturbance occurs. However, the presence of a disturbance that effects a substantial area of land or critical location on a slope is likely more important than the presence of invasive tree species. Non-native invasive species may contribute to the subsequent failure of a slope by excluding the development of ground cover, shrubs, and more deep-rooted native tree species. It is unlikely that their presence alone is a cause of large-scale slope failures along the bay given the number of stands that have non-native invasive species or are mixed and are apparently stable at the present time.

The literature review clearly identified that vegetation has a positive influence on slope stability through several well documented and researched mechanisms. The field survey showed that stands of native vegetation have characteristics that would contribute to increased slope stability including greater size class distribution, greater shrub and ground cover, and a larger number of mature, over story trees. The use of native tree species to re-vegetate slopes is a solid recommendation revealed by this project as is the use of management practices

that reduce the presence of Norway maple and ailanthus from invading the bay slopes.

The use of vegetation alone to attempt to stabilize slope failures is probably an unwise management approach give the steepness of the slopes and their highly erode able and non-cohesive soils. The use of both vegetative and engineering solutions, along with preventative measures that limit vegetation and soil disturbance, and manage water discharge from houses and drains on the top of the slopes will be needed.

The literature review showed that the use of biomechanical approaches to mitigate slope failures has been used extensively in the United States and other locations. A similar approach could likely be employed along the Irondequoit Bay to correct slope failures that have occurred. Our field survey showed that a large number of native species have the potential to contribute to re-stabilization of slopes that have failed if non-native invasive species can be excluded during re-vegetation efforts.

Photo 6. The German Village slide of 2004 threatened homes on the top and bottom of the slope. Contributing causes of the failure included the predominant tree species on the slope was non-native Norway maple, clearing of trees on the slope and the discharging of rain gutters on the slope from homes at the top of the slope.

Prevention of disturbances is the most effective solution to preserving the native plant communities and helping maintain the stability of the slopes. The survey reveled there are various activities that are being completed by property owners including tree pruning and clearing, and dumping that are having an adverse impact on the slope vegetation. Some of this work is being completed by for hire tree and landscape companies. In some or perhaps many of these cases the

property owners and for service companies do not know what the potential impact of these activities on these slopes and consequences of their actions.

Photo 7. Understory vegetation was cleared and trees were pruned excessively on this slope, allowing non-native invasive Norway maple and ailanthus to become established.

General Management Strategies and Recommendations

The following are general management strategies for addressing the vegetation management and slope failure issues identified in the field survey work. Specific management recommendations for each forest stand can be found in Appendix 2. There are four management goals that should guide the Town in these efforts.

- Minimize the disturbance of native stands on these critical slopes from
  - Site Development
  - Vegetation Removal
  - Tree Pruning
- Promote the removal of existing non-native plant species already established in most stands and planting of native plant species
- Promote the removal of non-native plant species and planting of native plant species in yards adjacent to the slopes
- Manage to preserve and enhance the native vegetation on these slopes at the stand structure level.
  - Overstory – Large and mature trees
  - Intermediate – Intermediate sized and maturing
  - Saplings – Young and small sized trees
  - Shrubs
  - Groundcover

The management options available to achieve these goals are as follows.

Vegetation Management

Vegetation management includes the pruning, removal or other methods to suppress the growth of non-native plant species. The objective is to enhance the environment for the growth of native and non-invasive plant species through wholesale or selective plant removal or tree pruning. The general recommendations are as follows and are listed in priority of their importance and potential for the Town to use on steep slopes.

Culling – physical removal or herbicidal killing of all non-native or invasive saplings, shrubs and groundcover. Herbicidal treatment of stumps is highly recommended after removing any non-native tree as they will aggressively stump and root sprout thus potentially increasing tree density after removal.

Selective Culling – selective removal of larger non-native or invasive tree species to alter environmental conditions in order to promote establishment of native plant communities and to remove large, non-native or invasive trees that are seed sources. Selective culling can be accomplished with herbicides, tree girdling or physical removal and herbicidal treatment of stumps.

Herbicidal Treatments – the use of herbicides to selectively kill non-native or invasive plant species. This approach may be more desirable than physical culling as it minimizes soil disturbance and the treated trees can be left in the stand. Dead trees provide some soil stabilization. All treatments should be made by New York State licensed and insured pesticide applicators. If applied properly, these treatments would have little environmental impact because then can be made directly to the tree with little potential for the products reaching the Bay.

Planting

The objective is to introduce native plant species into the stand. This included the planting of nursery grown plant material or seeding with plant mixtures within the stand, in disturbed areas or at the top or bottom of the slope. A list of recommended trees, shrubs and groundcover for planting can be found in Appendix 4.

Providing property owners with a list of desirable native tree species for planting on the top or bottom of slopes is highly recommended. Trees on the top of slopes provide a direct seed source for spread and establishment down slope. Planting lists should include trees that are large at maturity, under story trees, and native shrubs. Conversely, planting non-native or invasive plant should be prohibited.

Trees

The trees should be at least 5 feet in height. In disturbed areas, sunlight reaches the stand floor; groundcover vegetation is released and can grow several feet or more in height in one year. Seedling trees would be shaded out by this vegetation and will not survive. Trees of this height are available as whips, bare root stock or containerized plants.

A 1.5 inch diameter bare root trees would work best, however, they cost between $50 and $100 each. Native bare root trees can be difficult to find. Schichtel's Nursery, (7420 Peters Rd., Springville, NY 14141 (716) 648-4749) located south of Buffalo has an extensive selection of quality trees. They also offer delivering the trees with the roots "dipped" in a moisture retention gel and bagged. This practice increases plant survival and would be desirable as irrigating plantings on these slopes is not practical.

A containerized product that is worthy of use is offered by RPM Ecosystems LLC (rpmecosystems.com). These trees are grown using a process that results in the plant having a much more extensive root zone as compared to bare root plants. This would also be an advantage as the more roots a plant has the more moisture it can absorb from the soil. These plants are approximately $45 each.

Shrubs and Groundcover

Shrubs and groundcover may fall victim to deer and rodent browsing if planted in small numbers. The most effective option may be to seed areas with a mixture of shrubs and groundcover. Native seed reserves are probably adequate in most stands to provide the majority of re-vegetation. Availability of native seed for shrubs and ground covers will be difficult to find and disperse economically. The use of shrubs and acceptable ground covers and the tops and bottoms of slopes would provide seed sources for re-vegetation. Where quick establishment of ground cover vegetation is needed a commercial mixture (non-native species) as recommended below worked well on the German Village failure area.

- 10 % Blue Grass-common variety
- 60% Tall Fescue variety KY-31 or approved substitute
- 30% Fine fescue-common variety of creeping red fescue
- Hydromulch applied at a minimum of 1500 lbs per acre or at the highest manufactures rate
- Tacking agent- applied at a minimum of 60 lbs per acre or the at manufacturers highest rate

Management of Slope Failures Using Vegetation

Reestablishment of native vegetation on slopes that have failed or are in partial failure is a clear recommendation that can be made from this project. The bay slopes are in most cases too steep to rely on vegetation alone to create stability. However, engineering practices that are amenable to the use of vegetation will provide the best long-term, environmentally acceptable solutions for creating long term stability for slopes that have failed.

Engineering practices that allow for the integration of native trees, and for the culling and removal of non-native species are highly recommended. Non-native trees can be used to give short term slope protection by the use of topping or severe crown reduction, and then eventual removal. Native trees should be planted to provide long term stability. Native trees and plants of all types, shrubs, vines, small-stature and understory species, and large trees at maturity should be used. Ground cover vegetation, because of the need for quick establishment to protect soil could be commercial mixes of non-native grasses.

Regulatory Review and Implications

The Town Master Plan identified the steep slopes as a key planning issue primarily as it relates to development. For example, as described in the Introduction, D. Summary of Planning Issues; 1. Irondequoit Bay; 2nd paragraph (page 3). The plan also identifies protection of sensitive areas from adverse development and restricting development in areas with steep slopes as an environmental objective under the plan (pg.7). The Town Code (Article XI) also clearly defines what activities are regulated in Environmental Preservation Overlay Districts (EPOD). However, this code also primarily focuses on development and defines some vegetation management activities as exempt

under this chapter. It appears from the existing planning and regulatory documents in the Town that restricting the development of slopes has been the primary focus of their preservation and management.

However, educating property owners about the impact of their landscape management practices is clearly needed to help avoid and minimize disturbances on and near the slopes. Adopting additional legislative or regulatory statutes that limit the activities of property owners and tree and landscape service providers is a more aggressive method for the preservation of the slopes. This approach has precedent as the Town has interpreted the code as to allow the restriction of tree cutting on these slopes in the past.

A review of legislation from other communities showed that restricting vegetation management activities on private properties has been adopted in other municipalities. These could be used as examples of possible Code revisions or additions for the Town to consider. It is important to recognize that the strengthening the code will require additional funding and manpower to enforce and administer.

It is not uncommon to find language in municipal code requiring these service providers to retain a permit to work within the municipality (for example in the Town of Brighton, NY). Some municipalities merely require proof of adequate insurance and assess a fee. Other more aggressive codes require the passing of an exam to perform tree and landscape work (City of Fort Collins, Co.). If this approach to regulating tree and landscape services were added to the Town's municipal code it provides a potential opportunity to educate, restrict and enforce the removal and pruning of vegetation on the slopes.

An example of legislation that clearly defines the restriction of vegetation management activities on steep slopes can be found in "Preserving Natural Resources Through Local Environmental Laws: A Guidebook for Local Governments, Second Edition, December 2001 by the Land Use Law Center of Pace University School of Law" (http://law.wustl.edu/landuselaw/ssprotection.htm). A permit must be retained from the municipality in order to complete vegetation work on a steep slope. This would allow for a review of the proposed activities to ensure they are consistent with the recommendations of this plan. There are exemptions for "customary landscaping" which allows for the removal shrubs plants and trees less than 4 inches in diameter. This language is likely too liberal as it allows the removal of the important sapling, shrub and groundcover layers. The document does provide a good template that with some minor language changes could be useful to the Town.

Education and Legislation Recommendations

The management tools to prevent unwanted disturbance to vegetation and avoid undesirable management practices are education and legislation.

Education

We recommend that educational brochures for property owners and tree and landscape service providers be developed and distributed. The brochures should include the following information.

- The information retained in this report and the literature review regarding the environmental sensitive nature of these slopes and plant communities and thus the rational for these recommendation and legislation.
- A list of activities that are environmentally acceptable.
- A list of activities that are in accordance legally with the Town Code.
- The list of acceptable plant species for planting on the tops of slopes and within the stand as allowed by the Town Code.

Legislation

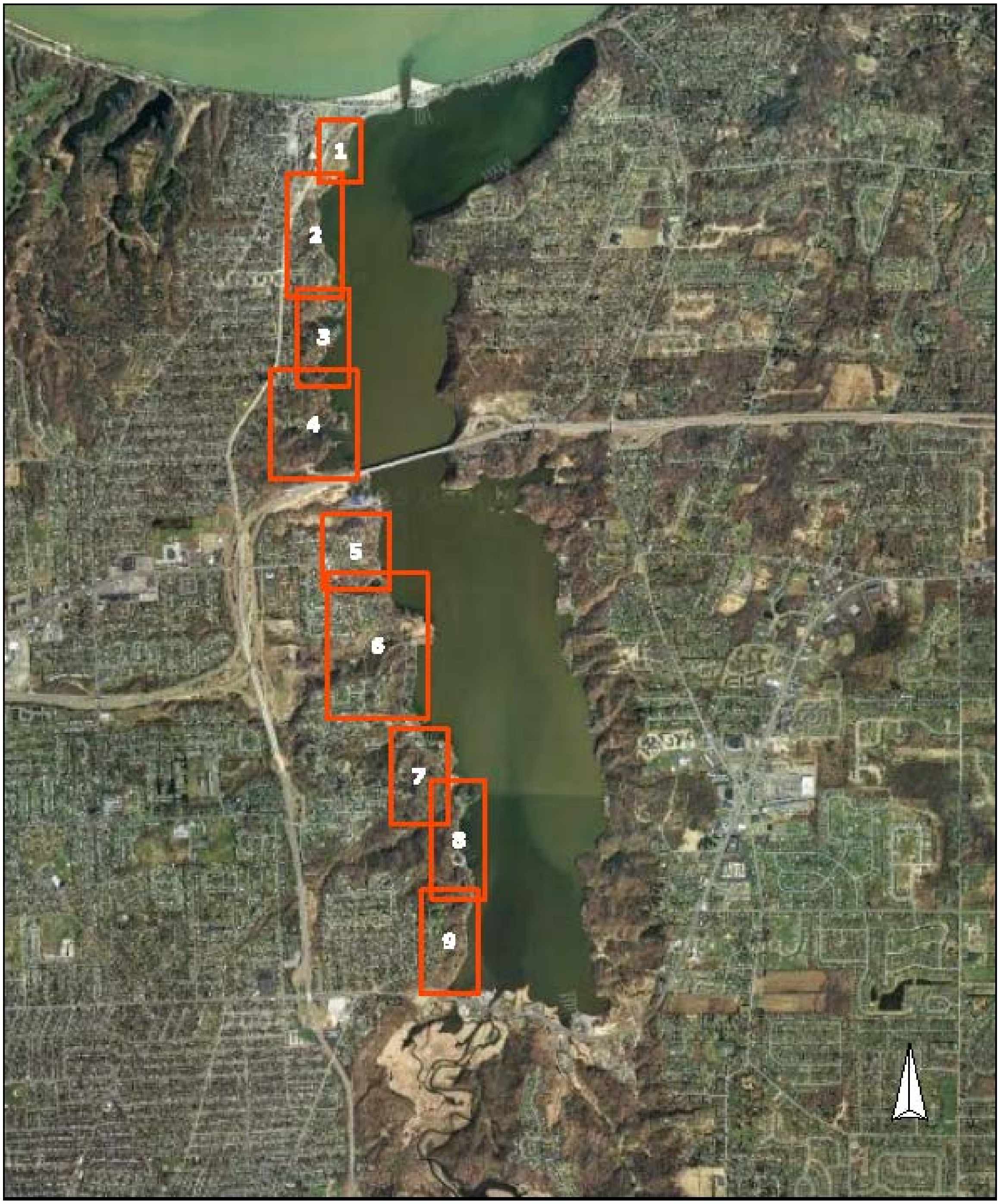
We recommended considering revision of the Town Code to clearly define restricted activities, such as tree pruning, dumping and vegetation clearing. For hire landscape and tree services could also be required to retain a license to work in the Town. Damages for code infractions should be defined including restoration of damages, fines and revocation of licenses for for-hire service companies. The Pace University School of Law language referenced above could be used as a template, however, if the Town chooses to take this more aggressive approach, the code should require a permit for any vegetation cutting rather than allowing the exemption as defined. The permit application should be reviewed by a forestry professional to insure that the specifications developed by the applicant are consistent with the findings of this plan.

Closing

The presence of recent large-scale slope failures on Bay slopes and the results of the slope vegetation survey clearly indicate there is a significant risk of slope failures in the future. The findings of the literature review and the slope vegetation survey and the recommendations in this plan reveal there are opportunities to reduce this risk. These steep slopes are a dynamic and complex ecosystem and their stability is the function of many factors including hydrology, vegetation management and human activities. As a result, reducing the risk of future slope failures will require a combination of management strategies addressing all of these factors. This plan focused on the management of the vegetation on these slopes. An aggressive and large scale implementation of the recommendations in this plan is likely neither realistic nor practical. However, implementing the educational and legislative recommendations, addressing the failure areas identified and implementing recommendations on a case by case are realistic and would result in positive steps toward preserving these slopes and this ecosystem.

The Town of Irondequoit is grateful for the grant funding provided by the Lake Ontario Coastal Initiative which made the completion of this project possible. Urban Forestry, LLC thanks the Town of Irondequoit for the opportunity to serve Town in developing this most interesting and important plan and look forward to the opportunity to serve the Town in the future.

Appendix 1. Stand Identification and Delineation Maps.



Reference Map

Slope Map # 1

Slope Map # 2

Slope Map # 3

Slope Map # 4

Slope Map # 5


Stand # 1
Stand # 2
Stand # 4
Stand # 3
Stand # 2
Stand # 1
Bay Shore Blvd
Bay View Rd

Slope Map # 6

Slope Map # 7

Slope Map # 8

Slope Map # 9

Appendix 2. Management Recommendations by Slope Map and Stand

The information is to assist the Town in developing stand specific management practices based on the type of vegetation and the slope characteristics that were identified in the field survey. Each stand was classified into being comprised of native, mixed, or invasive species. General management recommendations for each of these stand types are presented first and the stand specific recommendations next. The location of each stand and its boundaries are presented in Appendix 1.

Stand Type Specific Recommendations

Native Stands

Vegetation Management

Cull or remove all invasive tree species within the stand and along stand margins either by physically cutting them or using herbicide treatments. Treat the stumps with an herbicide to suppress sprouting. Removal of invasive species is an important and achievable goal (because of the low number of invasive species currently present) in these native stands, particularly in stands that are mature or over mature and where natural success ional changes (tree mortality related to age or windthrow) will likely occur in the future. These stands could easily be converted to significantly higher level of invasive species when these changes occur.

Planting

Seed with native plant mixes in disturbed areas created by vegetation management activities. Plant native plants in large disturbance area created by vegetation management activities.

Legislative

Prohibit any activities that will disturb these stands. Require permits for any activity within these stands. Prohibit any pruning of native trees. Encourage removal and stump treatment and pruning of invasive species.

Mixed Stands

Vegetation Management

Cull or remove all invasive tree species within the stand and along stand margins greater than 10 inches in diameter either by physically cutting them or using herbicide treatments. Treat the stumps with an herbicide to suppress sprouting. Removal of invasive species will be very difficult in these mixed stands because of the higher proportion of non-native trees. Culling larger diameter trees will

reduce seed sources and is probably the most efficient approach to slow the further encroachment of Norway maple and ailanthus.

Planting

Plant native plants in large disturbance area created by vegetation management activities. Seed with native plant mixes throughout the stand.

Legislative

Prohibit removal or pruning of native trees. Encourage removal and stump treatment of invasive species and planting of native species on the slope margins.

Invasive Stands

Vegetation Management

Cull or removing stands with large areas of primarily invasive Norway maple and ailanthus is like impractical because of the extent of area involved and the amount of follow-up replanting that would be needed. Creating opening where small areas of the stand are cleared of invasive trees and are planted with large (at maturity) native trees may be possible. It may also be possible to cull trees on the edges of these stands and replant the margins with native species. Culling selective large, non-native seed trees in these stands may also be practical.

Planting

Plant native plants in areas disturbed by vegetation management activities and along the margins. Seed with native plant mixes throughout the stand

Legislative

Be liberal by allowing removal and pruning of invasive species as long as native trees are planted when trees are removed and no native species are disturbed.

Specific Stand Recommendations
Slope Map1

There were no significant slopes within the area. There are no immediate vegetation or slope failure issues at the present and because of the minimal slope it is unlikely that issues will develop in the future.

Slope Map 2

Stand 1

Description

The stand type is mixed, intermediate in age and the vegetation cover is approximately 55%. The slopes are approximately 30-40% and appear stable. The over story trees are red oak and comprise approximately 25% of the trees. The intermediate species comprise approximately 20% of the trees and include white oak, black walnut, black cherry, Norway maple and ailanthus. Sapling trees are hemlock, black walnut, mulberry sassafras, and Norway maple and comprise approximately 78% of the trees. The shrub and groundcover layer is very sparse with a few privet and herbs. Invasive Norway maple and ailanthus comprises approximately 10% of the trees.

Treatment

Cull the Norway maple and ailanthus trees. Plant native shrubs and seed with ground cover.

Stand 2

Description

The stand type is invasive, young in age and vegetation cover is approximately 55%. This is the German Village slump failure. Slopes are approximately 30-40%. The over story trees are red oak at the top of the slope and comprise approximately 5% of the trees. The intermediate and sapling trees are Norway maple, ailanthus and some boxelder and comprise approximately 85% and 10% of the trees respectively. There is no shrub or groundcover layer.

Treatment

Manage the failure with engineering approaches and native vegetation reestablishment. Plant trees and shrubs in slope failure. Selectively cull the invasive species over multiple years and plant in the openings created by the culling. Seed with groundcover mix.

Stand 3

Description

The stand type is native, mature in age, primarily red oak with some invasive Norway maple and has approximately 30% vegetation cover. The slopes are approximately 25-30 % and appear stable. There is some dumping near the top edge. The overstory trees are red oak and comprise approximately 5% of the trees. The intermediate trees are red oak, pignut hickory and black cherry and comprise 45% of the trees. The sapling trees comprise approximately 50% of the trees and are red oak, red maple, pignut hickory, black cherry, hawthorn and dogwood. The shrub and groundcover layers comprise approximately 5% of the cover each and include viburnum and vacinnium shrubs and ferns groundcover. The invasive species is Norway maple and comprises approximately 5% of the cover.

Treatment

Cull the Norway maple and protect the native stand.

Stand 4

Description

The stand type is mixed, mature in age with approximately 75% vegetation cover of mature red oak and invasives. The slopes are approximately 35-40 percent and appear stable. There is some dumping at the top edge. The overstory trees are red oak and comprise approximately 20% of the trees. The intermediate species are Norway maple and boxelder and comprise approximately 10% of the trees. Sapling trees comprise approximately 70% of the trees and include Norway maple, ailanthus and boxelder. The shrub layer comprises approximately 1% of the trees and includes honeysuckle and privet. There is 1% groundcover that includes pokeweed, raspberry and grape. Approximately 50% the stand is invasive Norway maple and ailanthus.

Treatment

Cull the invasives, plant and seed. Protect the red oak trees.

Stand 5

Description

The stand type is native, mature in age, approximately 25% vegetation cover with mature oak overstory and clearing of the vegetation in the understory. The slopes are approximately 30-40% and appear stable. The overstory is

approximately 80% of the trees and is red oak. The intermediate trees comprise approximately 5% of the trees and include red oak and Norway maple. The saplings comprise approximately 15% of the trees and include ailanthus and Norway maple. There is approximately 2% shrub layer of honeysuckle and barley. The groundcover is approximately 95% including ivy and grasses. The invasives comprise approximately 20% of the stand and are Norway maple and ailanthus.

Treatment

Cull the Norway maple and ailanthus trees and plant trees and shrubs. Protect the oaks by restricting removal and pruning.

Stand 6

Description

The stand type is mixed, mature in age and there is approximately 45% vegetation cover. The slopes are approximately 35-40% and appear stable. Ten percent of the trees are overstory red oak and some white oak. The intermediate trees are approximately 70% of the trees and include red oak and Norway maple. The sapling trees are approximately 20% of the trees and include Norway maple, pignut hickory an black cherry. There is a approximately 1% shrub layer cover of amelanchier. There is 0% groundcover. The invasive is Norway maple and comprises approximately 5% of the cover.

Treatment

Cull the Norway maple and plant. Preserve and protect the native plants.

Stand 7

Description

The stand type is invasive, intermediate in age and there is approximately 45% vegetation cover. The slopes are approximately 35-40% and appear stable. There has been filling disturbance. There are no overstory trees. Approximately 60% of the trees are intermediate and include primarily Norway maple, some cottonwood, ailanthus and black locust. The saplings are approximately 40% of the trees and include Norway maple. Cottonwood, quacking aspen, ailanthus, pignut hickory and some red oak at the top of the slope. There is an approximately 2% shrub layer of autumn olive, pea shrub and honeysuckle. There is an approximately 1% groundcover layer of herbs. The invasives comprise approximately 80% of the cover and include Norway maple and ailanthus.

Treatment

Cull the invasives and plant.

Slope Map 3

Stand 1

Description

The stand type is mixed, intermediate in age and there is approximately 45% vegetation cover. The slopes are approximately 35-40% and in failure, classified as a slide/slump. Approximately 60% of the slope is in failure primarily around ground water seepage to the surface. Overstory trees comprise approximately 10% of the trees and include sugar maple and red and white oak on the northern edge. Intermediate trees are approximately 60% of the trees and include Norway maple, ailanthus, black cherry and American beech. Saplings comprise 30% of the trees and include invasives Norway maple and ailanthus. Shrub and groundcover layers comprise less than 1% aver the slope area. Invasive species comprise approximately 50% of the stand and are primarily Norway maple with ailanthus on the northern edge of the stand.

Treatment

Stabalize the slope failure. Selectively cull intermediate invasives within the stand and plant in culling areas. Cull invasives on margins of the stand and plant.

Stand 2

Description

The stand type is mixed, intermediate in age and there is approximately 65% vegetation cover. The slopes are approximately 35-40% and appear stable. There is sign of previous disturbance. The overstory is white and red oak and comprise approximately 5% of the trees. Intermediate species comprise 90% of the trees and include Norway maple, white oak, sycamore maple, pignut hickory and black walnut. Sapling trees comprise approximately 5% of the trees and include Norway maple and ailanthus. There is 0% of the area covered by shrubs and groundcover.

Treatment

Cull young invasives. Selectively cull larger invasives and plant in openings created by culling. Seed with groundcover mix.

Stand 3

Description

The stand type is mixed, intermediate in age and there is approximately 55% vegetation cover. The top of the slope is primarily invasive the bottom is mixed. The slopes are approximately 35-40% and appear stable. The slope is classified as disturbed and there has been cutting. The overstory trees including hemlock and white pine comprise approximately 5% of the trees. The intermediates comprise approximately 90% of the trees and include red oak, pignut hickory, white pine, hemlock, black cherry, Norway maple and American beech. The saplings are sparse, approximately 5% of the trees and are Norway maple and ailanthus. There is no shrub layer and approximately 2% groundcover of bittersweet. Invasives comprise approximately 20% of the vegetation cover and Norway and sycamore maple and ailanthus.

Treatment

Cull all small invasives. Cull selective larger invasives and plant in openings created by culling. Seed with ground cover.

Stand 4

Description

The stand type is mixed, mature in age and there is approximately 45% vegetation cover. The slopes are approximately 35-40% and appear stable. The site is disturbed and cutting has been completed at the top of the slope. The overstory comprises approximately 20% of the trees and includes red oak, hemlock , yellow birch and pignut hickory. The intermediate species comprise approximately 20% of the trees and are red oak, yellow birch, white pine and Norway maple. The saplings are all Norway maple and comprise approximately 60% of the trees. The shrub and groundcover layers comprise 1% each onf the area and include hawthorn and ferns. The invasive species comprise approximately 15% of the vegetation cover and are exclusively Norway maple.

Treatment

Cull the invasives.

Stand 5

Description

The stand type is mixed, over-mature in age and the vegetation cover is approximately 60%. The slopes are disturbed by cutting at the top of the slope.

There is a wind fall failure on the south end of the stand. The overstory comprises approximately 20% of the trees and includes native red, black and white oak. The intermediates trees include cherry, sassafrass, and Norway maple and comprise approximately 50% of the trees. Sapling trees are exclusively Norway maple and comprise approximately 30% of the trees. There is an approximately 1% shrub layer of honeysuckle and groundcover is abscent.

Treatment

Cull the invasives. Plant in the wind fall disturbance area. Seed with groundcover mix.

Stand 6

Description

The stand type is mixed, intermediate in age and the vegetation cover is approximately 55%. The slopes are approximately 35% and appear stable. One-percent of the trees are overstory and include black, red and white oak. The intermediate trees comprise approximately 30% of the trees and include red oak, pignut hickory, sasafrass and mazzard cherry. Saplings comprise approximately 69% of the trees and include pignut chickory, cherry, crabapple, Norway maple, sasafrass, and red oak. There is an approximately 5% shrub layer of ameleanchier and approximately 5% groundcover layer of grasses. Five-percent of the cover is invasive Norway maple.

Treatment

Cull the invasives.

Slope Map 4

Stand 1

Description

The stand type is native, intermediate in age and the vegetation cover is approximately 40%. Slopes are approximately 30% and appear stable. The overstory trees are primarily white oak, some red oak and comprise approximately 15% of the trees. The intermediate trees comprise approximately 10% of the trees and include white oak and red maple. Approximately 75% of the trees are saplings and include red and sugar maple, black cherry and white oak. There is whitchhazael and autumn olive in the shrub layer and grasses occupying approximately 5% of the area. Invasive species have not encroached in this stand.

Treatment

The stand should be preserved and protected.

Stand 2

Description

The stand type is native, mature in age and the vegetation cover is approximately 45%. The slopes are approximately 30-35% and appear stable. The overstory includes black, red, and white oak, black walnut and sugar maple and comprises approximately 35% of the trees. The intermediates comprise approximately 15% of the trees and includered oak, sugar maple, black cherry and tulip poplar. The saplings comprise approximately 50% of the trees and included sugar maple, black cherry and Norway maple primarily on the edges of the stand. The shrub and groundcover layers comprise less than 1% of the stand respectively. Invasive Norway maple is primarily restricted to the stand edges.

Treatment

Cull invasives.

Slope Map 5

Stand 1

Description

The stand type is mixed, intermediate in age and the vegetation cover is approximately 20%. Slopes are approximately 25-30% and appear stable. There are no overstory trees. The intermediates trees comprise approximately 80% of the trees and include Norway maple, sasafrass, pignut hickory, black cherry and cottonwood. The saplings comprise approximately 20% of the trees and include sasafrass, pignut hickory, and Norway maple. There is an approximately 10% shrub cover of honeysuckle. There is extensive groundcover of oriental bittersweet, crown vetch, and herbs. Invasives represent approximately 70% of the cover and are predominately Norway maple.

Treatment

Cull invasives and plant. Restrict further cutting or disturbance.

Stand 2

Description

The stand type is native, over-mature in age and the vegetation cover is approximately 35%. Slopes are approximately 25-35% and appear stable. There has been clearing and pruning of the trees. The overstroy trees comprise approximately 50% of the trees and include red and white oak, tulip polar and white pine. The intermediate trees include Norway maple, American beech pignut hickory, ironwood and black cherry and comprise approximately 40% of the trees. The saplings are black cherry, Norway maple and sasafrass and comprise approximately 10% of the trees. There is an approximately 2% shrub layer cover of witchhazel. The invasives are Norway maple and comprise approximately 5% of the vegetation cover.

Treatment

Restrict the tree pruning and clearing. Cull the Norway maple and plant.

Stand 3

Description

The stand type is mixed, mature in age and vegetation cover is approximately 35%. The slopes are approximately 30% and appear stable. The overstory trees comprise approximately 30% of the trees and include red, oak, pignut hickory, Norway maple and tulip poplar. The intermediate trees are Norway and sugar maple, red oak, hickory, black cherry and ailanthus and comprise approximately 60% of the trees. The saplings, at approximately 10% of the trees, include Norway maple, black cherry and ironwood. There is no shrub layer and the groundcover of ferns covers less than 1% of the area. The invasives comprise approximately 25% of the cover and include Norway maple and ailanthus.

Treatment

Cull the invasives and plant in culled areas or disturbed areas.

Stand 4

Description

The stand type is invasive, intermediate in age and the vegetation cover is approximately 35%. The slopes are approximately 25-30% and approximately approximately 50% of the slope has a slide failure. There recent clearing and cutting particularly along the northern edge. The overstory trees comprise approximately 10% of the trees and include Norway maple, cottonwood and red oak, tulip poplar sugar maple in limited numbers. The intermediate trees include Norway maple and sasafrass and comprise approximately 80% of the trees. Saplings comprise approximately 10% of the trees and include Norway maple and ailanthus. There is a less than 1% shrub cover of multifloral rose and an

approximately 2% ground cover of pokeweed and bittersweet. The invasives comprise approximately 95% of the cover.

Treatment

Selectively cull invasives and plant in areas created by culling. Repeat the process over multiple years. Evaluate the slide to determine if engineering treatments may be required.

Stand 5

Description

The stand type is native, young in age and the vegetation cover is approximately 75%. The slopes are 2 approximately 5% and appear stable. There are no overstory or intermediate trees. This is a young “dog-hair” stand of primarily sasafrass with scattered ailanthus and Norway maple. There is an approximately 10% shrub cover layer of honeysuckle and an approximately 5% cover layer of bittersweet. The invasive Norway maple and ailanthus comprise approximately 15% of the cover.

Treatment

Cull the Norway maple and ailanthus and preserve the sasafrass.

Stand 6

Description

The stand type is mixed, intermediate in age and the vegetation cover is approximately 45%. The slopes are approximately 25% and appear stable. There has been some cutting on the top and into the middle of the slope. There are no pverstory trees. The intermediate trees are approximately 90% of the trees and include pignut hickory, sasafrass, Norway maple and some black cherry and red oak. The saplings include Norway maple, sasafrass and black cherry and comprise approximately 10% of the trees. There is some privet , bittersweet, virginia creeper and pokeweed however they cover well below 1% of the area. Invasive Norway maple is approximately 50% of the trees.

Treatment

Cull the Norway maple.

Stand 7

Description

The stand type is mixed, intermediate in age and the vegetation cover is approximately 55%. There has been some clearing and cutting at the top of the slope. The slopes are approximately 30% and appear stable. The overstory trees are red oak, Norway maple and black cherry and comprise approximately 30% of the trees. The intermediate trees comprise approximately 65% of the trees and include Norway maple, white pine and red oak. The saplings are approximately 5% of the trees and include Norway maple and black cherry. There is no shrub layer and pokeweed covers less than 1% of the area. Invassive Norway maple comprises approximately 50% of the trees.

Treatment

Cull Norway maple saplings. Selectively cull larger Norway maples across the stand and plant in the culled areas. Restrict the active vegetation cutting on the top of the slope.

Stand 8

Description

The stand type is invasive, young in age and the vegetation cover is approximately 100%. The slopes are approximately 25% and appear stable. There are no overstory or intermediate trees. The saplings are black cherry, ailanthus and boxelder. There is sumac, pokeweed, bittersweet and goldenrod present. The invasive ailanthus is approximately 50% of the trees.

Treatment

Cull the invasives. Plant seed trees.

Slope Map 6

Stand 1

Description

The stand type is invasive, intermediate in age and the vegetation cover is approximately 20%. The slopes are approximately 20% and appear stable. The overstory trees comprise approximately 25% of the trees and include black walnut, white ash, white pine, cottonwood and sasafrass. Intermediate trees include quacking aspen and comprise approximately 20% of the trees. Saplings comprise approximately 5% of the trees and include sumac, white ash, and black walnut. There is an approximately 10% shrub cover of honeysuckle and grape and an approximately 100% groundcover of boneset, goldenrod, raspberry, and

herbs. The stand was previously cleared and includes some invasive norway maple.

Treatment

Cull the Norway maple and plant oak or sugar maple seed trees.

Stand 2

Description

The stand type is native, mature in age and the vegetation cover is approximately 35%. The slopes are approximately 28-30% and appear stable however the site is disturbed by building.   The overstory trees are red oak and comprise approximately 10% of the trees. The intermediate trees comprise approximately 75% of the trees and include red oak, sugar maple, yellow birch, cottonwood, Norway spruce and white pine. The sapling trees include sugar maple, red oak, yellow birch pignut hickory and white ash and comprise approximately 15% of the trees. There is an approximately 2% shrub cover of privet, buckthorn, autumn olive, honeysuckle, and oreiental bittersweet and an approximately 5% groundcover of lilly of the valley. Invasive Norway maple comprises approximately 5% of the cover.

Treatment

Limit further disruption from the building activities. Cull the Norway maple and plant after construction is complete.

Stand 3

Description

The stand type is native, mature in age and the vegetation cover is approximately 25%. The slopes are approximately 40% and appear stable. There has been some clearing at the top of the slope. The overstory trees comprise approximately 10% of the trees and include primarily red oak with some cottonwood pignut hickory and white pine. The intermediate trees include white pine, red oak, red maple, cottonwood, black locust and Norway maple and comprise approximately 5% of the trees. The saplings comprise approximately 85% of the trees and include Norway maple, sasafrass, red maple and ailanthus. There is an approximately 5% shrub cover of grape, honeysuckle and sumac and a heavy groundcover layer of herbs and vines near the top of the slope. Invasive Norway maple comprises approximately 5% of the cover.

Treatment

Protect the mature oaks from further disruption or cutting. Cull the Norway maple and ailanthus.

Stand 4

Description

The stand type is native, intermediate in age and the vegetation cover is approximately 45%. The slopes are approximately 40% and appear stable. The overstory trees are red oak, Norway maple, pignut hickory, black cherry and white pine and comprise approximately 10% of the trees. The intermediate trees comprise approximately 75% of the trees and include sugar maple, black cherry and pignut hickory. The sapling include sugar maple and American beech and comprise approximately 15% of the trees. There is an approximately 1% shrub cover of witchhazel and an approximately 5% groundcover of ferns. Invasive Norway maple comprises approximately 5% of the cover and is located primarily along the road cut.

Treatment

Preserve the natives and cull the Norway maple.

Slope Map 7

Stand 1

Description

The stand type is native, mature in age the stand cover is approximately 50%. The slopes are approximately 25-35% and appear stable. Thee has been clearing and pruning. The overstory includes red oak, tulip poplar, sugar maple and yellow birch and comprises approximately 10% of the trees. The intermediate trees comprise approximately 75% of the trees and include tulip poplar, sugar maple, red maple, red oak, white pine, American beech and sasafrass. The saplings include pirgnut hickory, sugar maple and the other trees listed above. There is a witch hazel shrub layer and a groundcover of less than 1% including ferns, mayapple, and bittersweet. Invasive Norway maple is present.

Treatment

Preserve and protect the stand. Seed with groundcover mix. Cull the Norway maple trees.

Stand 2

Description

The stand type is native, intermediate in age and the vegetation cover is approximately 25%. The slopes are approximately 30% and appear stable. There is a road cut through the stand with some invasives on the margins. There are no overstory trees. The intermediate trees comprise approximately 50% of the stand and include white and red oak, basswood and pignut hickory. The saplings comprise approximately 50% of the trees and include sasafrass, pignut hickory and red oak. There is an approximately 2% shrub layer of autumn alive and privet and an approximately 5% groundcover layer of grasses.

Treatment

Preserve and protect the stand.

Stand 3

Description

The stand type is native, mature in age and the vegetation cover is approximately 35%. The slopes are approximately 20-25% and appear stable. The overstory trees comprise approximately 10% of the trees and include red and white oak, pignut hickory, tulip poplar and red maple. The intermediate trees include sasafrass, red oak, American beech, black cherry and red maple and comprise approximately 85% of the trees. The saplings comprise approximately 5% of the trees and include red maple, hawthorn and pignut hickory. There is a 1% shrub layer of privet and an approximately 1% groundcover layer of oriental bittersweet and grasses.

Treatment

Preserve and protect the stand. Seed with groundcover mix.

Slope Map 8

Stand 1

Description

The stand type is native, mature in age and the vegetation cover is approximately 45%. The slopes are approximately 30% and appear stable. There is a road traversing the stand. The overstory trees comprise approximately 15% of the trees and include black, red and white oak, pignut hickory, tulip poplar and white pine. The intermediate trees include pignut hickory, oak, dogwood, black cherry, and red maple and comprise approximately 15% of the trees. The saplings comprise approximately 70% of the trees and include pignut hickory, red oak,

sasafrass, black cherry and sugar maple.   There is some maelanchier and witchhazel shrubs and an approximately 20% groundcover of mayapple and grasses. This is the Monroe County park land. There is invasive ailanthus and Norway maple along the road margins.

Treatment

Preserve and protect the native stand. Cull the Norway maple and ailanthus.

Stand 2

Description

The stand type is native, intermediate in age and the vegetation cover is approximately 55%. The slopes are approximately 15-20% and there is a small failure on Scheneider Island. The overstory trees are red and white oak and pignut hickory and comprise approximately 5% of the trees. The intermediate trees comprise 50% of the trees and include red oak, red maple, pignut hickory, American elm and sasafrass. The saplings include the same trees and comprise approximately 45% of the trees. There is an approximately 5% shrub cover of witch hazel, autumn olive, honeysuckle and blueberry. There is an approximately 2% groundcover of grasses. There is cottonwood and black willow on the margins of the stand.

Treatment

Preserve and protect the stand.

Slope Map 9

Stand 1

Description

The stand type is mixed, intermediate in age and the vegetation cover is approximately approximately 55%. The slopes are approximately 30% and appear stable. There as been clear and cutting on the top of the slopes. The stand is approximately 75% black locust, approximately 15% ailanthus and Norway maple, approximately 10% black walnut with scattered mature oaks. The saplings include black walnut, pignut hickory, white ash, sasafrass, Norway maple, black locust, and ailanthus. There is an approximately 10% shrub cover of honeysuckle and multifloral. The groundcover is approximately 5% and includes oriental bittersweet, pokeweed and raspberry.

Treatment

Cull the sapling Norway maple and ailanthus and the multifloral rose. Selectively cull the larger Norway maple and ailanthus and plant. Preserve and protect the natives.

Stand 2

Description

The stand type is mixed, matire in age and the vegetation cover is approximately 55%. The slopes are approximately 35% and appear stable. There has been clearing cutting and dumping on the top of the slopes. The stand is native oak hickory with some larger Norway maple. There is approximately 30% red oak, 30% white oak, 10% sasafrass, 10% sugar maple, 10% pignut hickory, 2% Norway maple and scattered black cherry and black walnut. The saplings include pignut hickory and Norway maple. There is an approximately 10% shrub cover of privet and honeysuckle. There is an approximately 5% groundcover of oriental bittersweet.

Treatment

Cull the Norway maple. Preserve and protect the natives. Restrict cutting and dumping on the tops of the slopes. Seed with a groundcover mix.

Stand 3

Description

The stand type is mixed, intermediate in age and there is approximately 55% vegetation cover. The Slopes are less than approximately 20% and appear stable. The stand is mostly native oak hickory with a heavy native sapling population and some invasives. There is approximately 30% red oak, 50% pignut hickory, 10% cottonwood, 5% black cherry, 2% Norway maple and 3% other natives. The saplings are approximately 20% of the cover and include pignut hickory, sasafrass, black cherry, sweet birch and some Norway maple. There is very little shrub or groundcover with some bittersweet observed.

Treatment

Cull the Norway maple. Preserve and protect the natives. Seed with groundcover mix.

Stand 4

Description

The stand type is native, mature in age and the vegetation cover is approximately 65%. The slopes are 2 approximately 5-30% and appear stable. The overstory is approximately 40% of the trees and includes red oak, black cherry and pignut hickory. The intermediate trees include black cherry, Norway maple and pignut hickory and comprise approximately 40% of the trees. The saplings comprise approximately 20% of the trees and include hawthorn, ironwood, black cherry and Norway maple. There is no shrub or ground cover layer.

Treatment

Cull the Norway maple and preserve and protect the natives. Seed with groundcover mix.

Stand 5

Description

The stand type is native and mature in age. The slopes are approximately 25-55% and appear stable. The overstroy comprises approximately 60% of the trees and includes read and black oak and black walnut. The intermediate trees include read oak, pignut hickory and black cherry and comprise approximately 15% of the trees. The saplings comprise 2 approximately 5% of the trees and include Norway maple, black cherry and hawthorn. There is no shrub cover and groundcover of raspberry, boneset and beggerstick was observed.

Treatment

Cull the Norway maple. Preserve and protect the natives. Seed with a groundcover mix. There is a 55% slope on the south edge of the stand with mature oak and hickory and a house at the base. The vegetation on this slope should not be disturbed.

Stand 6

Description

The stand type is mixed and young in age. The slopes are approximately 45% and appear stable. The overstory trees include cottonwood, Norway maple, black walnut, red oak, tulip poplar and pignut hickory and comprise approximately 40% of the trees. The intermediate trees comprise approximately 10% of the trees and include red oak, Norway maple and ailanthus. The saplings include hawthorn, Norway maple and red oak and comprise approximately 60% of the trees. There is some honeysuckle and barberry shrubs and grape and raspberry groundcover.

Treatment

Cull the Norway maple and ailanthus and plant in the areas culled.

Stand 7

Description

The stand type is native and intermediate in age. The slopes are approximately 30% and appear stable. The stand includes red and white oak, tulip poplar, pignut and shagbark hickory and very little invasive Norway maple. There is some witchhazel and sparse groundcover.

Treatment

Cull the Norway maple. Preserve and protect the natives.

Appendix 3. Observed Plant Species

References

Dirr, Micheal A. 1998. Manual of Woody Landscape Plants. Stipes Publishing LLC Champaign, Ill.
Leopold, Donald J. 2005. Native Plants of the Northeast. Timber Press Inc. Portland, Or.

Genus species - Common Name	**Native**	**Invasive**
Trees	**Species**	**Species**
Acer negundo - Boxelder	Yes	Yes
Acer platanoides - Norway Maple	No	Yes
Acer pseudoplatanus - Sycamore Maple	No	Yes
Acer rubrum - Red Maple	Yes	Yes
Acer saccharum - Sugar Maple	Yes	No
Ailanthus altissima - Tree of Heaven	No	Yes
Amelanchier species - Serviceberry Species	Yes	No
Betula alleghaniensis - Yellow Birch	Yes	No
Betula lenta - Sweet Birch	Yes	No
Carya glabra - Pignut Hickory	Yes	No
Carya ovata - Shagbark Hickory	Yes	No
Cornus florida - Flowering Dogwood	Yes	No
Crataegus species - Hawthorn species	Yes	No
Fagus grandiflora - American Beech	Yes	No
Fraxinus americana - White Ash	Yes	Yes
Juglans cinerea - Butternut	Yes	No
Juglans nigra - Black Walnut	Yes	No
Lirodendron tulipifera - Tuliptree	Yes	No
Morus alba - White Mulberry	Yes	Yes
Ostria virginiana - Ironwood	Yes	No
Picea abies - Norway Spruce	No	No
Pinus strobus - Eastern White Pine	Yes	No
Populus deltoides - Cottonwood	Yes	Yes
Populus tremuloides - Quaking Aspen	Yes	Yes
Prunus avium- Mazard Cherry	Yes	No
Prunus serotina - Black Cherry	Yes	No
Quercus acutissima - Sawtooth Oak	Yes	No
Quercus alba - White Oak	Yes	No
Quercus rubra - Red Oak	Yes	No
Quercus velutina - Black Oak	Yes	No
Rhus typhina - Staghorn Sumac	Yes	Yes
Robinia psuedoacacia - Black Locust	Yes	Yes
Salix alba - White Willow	Yes	Yes
Salix nigra - Black Willow	Yes	Yes
Tsuga canadensis - Eastern Hemlock	Yes	No

Genus species - Common Name	**Native**	**Invasive**
Shrubs	**Species**	**Species**
Caragana species - Peashrub species	No	no
Elaeagnus umbellata - Autumn Olive	No	yes
Hamamelis virginiana - Common Witchhazel	Yes	No
Ligustrum vulgare - Common Privet	No	Yes
Lonicera species - Honeysuckle species	No	Yes
Vaccinium angustifolium - Lowbush Blueberry	Yes	No
Viburnum opulus - Cranberrybush Viburnum	No	No
Groundcover		
Agrostis perennans - Grasses	Yes	No
Bidens frondosus - Beggerstick	Yes	No
Celastrus orbiculatus - Oriental Bittersweet	No	Yes
Convallaria majalis - Lily of the Valley	Yes	No
Eupatorium perfoliatum - Bonset	Yes	No
Ferns	yes	No
Hedera species - Ivy	No	Yes
Herbs	Yes	No
Parthenocissus quinquefolia - Virginia Creeper	Yes	No
Phytolacca americana - Pokeweed	Yes	No
Podophyllum peltatum - Mayapple	Yes	No
Rosa multiflora - Multiflora Rose	No	Yes
Rubus odoratus - Flowering Raspberry	Yes	No
Securigera varia - Crown Vetch	No	Yes
Solidago species - Goldenrod	Yes	No
Vitis labrusca - Wild Grape	Yes	Yes

Appendix 4. Recommended Planting List

Adapted from http://www.fhwa.dot.gov/environment/rdsduse/ny.htm

Recommended Flora Reference

Mitchell, R.S. & G. C. Tucker. 1997. Revised Checklist of New York State Plants. Contr. to a Flora of N.Y. State, Checklist IV New York State Mus. Bull. 790. 400 pp.

Native Plants for Landscape Use in New York

Note some of the ferns, grasses and forbes (herbs) may not be suited for use in wooded situations.

Ferns

Adiantum pedatum (northern maidenhair fern)
Asplenium platyneuron (ebony spleenwort)
Asplenium trichomanes (maidenhair spleenwort)
Athyrium filix-femina (lady fern)
Botrychium virginianum (rattlesnake fern)
Cystopteris bulbifera (bladder fern)
Cystopteris fragilis (fragile fern)
Dryopteris carthusiana (shield fern, toothed wood fern, spinulose shield fern)
Dryopteris cristata (crested wood fern, buckler fern)
Dryopteris marginalis (marginal wood fern)
Gymnocarpium dryopteris (oak fern)
Matteuccia struthiopteris (ostrich fern)
Onoclea sensibilis (sensitive fern, bead fern)
Osmunda cinnamomea (cinnamon fern)
Osmunda claytoniana (interrupted fern)
Osmunda regalis (royal fern)
Phegopteris hexagonoptera (broad beech fern)
Polystichum acrostichoides (Christmas fern)
Thelypteris novaboracensis (New York fern, tapering fern)
Thelypteris simulata (Massachusetts fern)
Woodsia ilvensis (rusty woodsia)
Woodwardia areolata (netted chain fern)
Woodwardia virginica (Virginia chain fern)

Forbs (annuals/biennials)

Corydalis sempervirens (pale corydalis)
Gentianopsis crinita (fringed gentian)
Lobelia spicata (pale lobelia)
Oenothera biennis (common evening primrose)

Forbs (perennials)

Acorus calamus (sweet flag, calamus)
Actaea pachypoda (white baneberry)
Allium canadense (wild garlic)
Allium tricoccum (wild leek)
Anaphalis margaritacea (pearly everlasting)
Anemone canadensis (Canada anemone, windflower)
Anemone cylindrica (thimbleweed, candle anemone)
Anemone virginiana (thimbleweed, tall anemone)
Antennaria spp. (pussytoes, everlasting)
Apocynum androsaemifolium (spreading dogbane)
Aquilegia canadensis (columbine)
Arisaema triphyllum Back-in-the-pulpit, Indian turnip)
Asarum canadense (wild ginger)
Asclepias incarnata (swamp milkweed)
Asclepias tuberosa (butterfly weed)
Aster divaricatus (white wood aster)
Aster dumosus (bushy aster)
Aster ericoides (heath aster, white wreath aster)
Aster laevis (smooth aster)
Aster novae-angliae (New England aster)
Aster novi-belgii (New York aster)
Aster pilosus (frost aster)
Astragalus canadensis (milk vetch, Canada milk vetch)
Caltha palustris (marsh marigold, cowslip)
Campanula rotundifolia (harebell)
Cardamine diphylla (two-leaved toothwort)
Caulophyllum thalictroides (blue cohosh)
Chelone glabra (turtlehead)
Cimicifuga racemosa (bugbane, black cohosh)
Claytonia caroliniana (broad-leaved spring beauty)
Claytonia virginica (narrow-leaved spring beauty)
Clintonia borealis (clintonia, blue-bead lily)
Collinsonia canadensis (stoneroot, citronella horsebalm)
Coptis trifolia ssp. groenlandica (goldthread)
Cornus canadensis (bunchberry)
Desmodium canadense (Canada tick-trefoil, Canada tickclover)
Dicentra cucullaria (Dutchman's breeches)
Epilobium angustifolium (fireweed, willow herb)
Erythronium americanum (eastern trout lily, yellow trout lily)
Eupatorium fistulosum (Joe-pye weed)
Eupatorium maculatum (spotted Joe-pye weed)
Eupatorium perfoliatum (boneset)
Eupatorium rugosum (white snakeroot)
Eupatorium purpureum (Joe-pye weed)

Euphorbia corollata (flowering spurge)
Euthamia graminifolia var. graminifolia (grass-leaved goldenrod)
Fragaria virginiana (wild strawberry)
Galium triflorum (sweet-scented bedstraw)
Gentiana andrewsii (bottle gentian)
Gentiana clausa (bottle gentian)
Gentiana saponaria (closed gentian, soapwort gentian)
Geranium maculatum (wild geranium, cranesbill)
Geum rivale (purple avens, water avens)
Helenium autumnale (common sneezeweed)
Helianthus divaricatus (narrow-leaved sunflower, swamp sunflower)
Helianthus strumosus (woodland sunflower)
Heliopsis helianthoides (ox-eye sunflower, false sunflower)
Hepatica nobilis var. acuta (sharp-lobed hepatica)
Heuchera american (alumroot)
Houstonia caerulea (bluets)
Houstonia longifolia (long-leaved bluets, pale bluets)
Hydrophyllum virginianum (Virginia waterleaf)
Hypericum ascyron (great St. John's wort)
Hypoxis hirsuta (yellow star grass)
Iris versicolor (blue flag)
Lespedeza capitata (roundheaded bush clover)
Lilium canadense (wild yellow lily, Canada lily)
Lilium philadelphicum (wood lily)
Linnaea borealis (twinflower)
Linum virginianum (woodland flax)
Lobelia cardinalis (cardinal flower)
Lobelia siphilitica (great blue lobelia)
Lupinus perennis (wild lupine)
Lysimachia ciliata (fringed loosestrife)
Maianthemum canadense (wild lily-of-the-valley, Canada mayflower)
Maianthemum racemosum ssp. racemosum (false Solomon's seal, false spikenard)
Maianthemum stellatum (starry Solomon's seal)
Mitchella repens (partridge berry)
Monarda didyma (beebalm, oswego tea)
Monarda fistulosa (wild bergamot, horsemint, beebalm)
Nuphar lutea (yellow pond lily, cow lily, spatter dock)
Oenothera fruticosa (sundrops)
Osmorhiza claytoni (sweet cicely, sweet jarvil)
Peltandra virginica (arrow arum)
Penstemon digitalis (beardtongue)
Penstemon hirsutus (hairy beardtongue)
Potentilla fruticosa (potentilla, shrubby cinquefoil)
Phlox paniculata (summer phlox, perennial phlox)
Physostegia virginiana (obedient plant, false dragonhead)
Podophyllum peltatum (May apple)

Polemonium reptans (Jacob's ladder, Greek valerian)
Polygonatum biflorum (Solomon's seal)
Potentilla arguta (white cinquefoil, prairie cinquefoil, tall cinquefoil)
Potentilla simplex (common cinquefoil)
Pycnanthemum tenuifolium (slender mountain mint)
Pycnanthemum virginianum (mountain mint)
Pyrola elliptica (shinleaf)
Ranunculus hispidus (early buttercup, tufted buttercup)
Rhexia virginica (meadow beauty)
Rudbeckia laciniata (cut-leaf coneflower)
Salvia lyrata (cancer weed, lyre-leaf sage)
Sanguinaria candensis (bloodroot)
Senecio aureus (golden ragwort)
Potentilla tridentata (three-toothed cinquefoil)
Silene stellata (starry campion)
Sisyrinchium angustifolium (narrow-leaved blue-eyed grass)
Solidago caesia (blue-stemmed goldenrod, wreath goldenrod)
Solidago canadensis (meadow goldenrod)
Solidago juncea (early goldenrod, plume goldenrod)
Solidago nemoralis (gray goldenrod,. old-field goldenrod)
Solidago odora (sweet goldenrod)
Solidago rugosa (rough-leaved goldenrod)
Solidago sempervirens (seaside goldenrod)
Solidago speciosa (showy goldenrod)
Solidago ulmifolia (elm-leaved goldenrod)
Streptopus roseus (rosy twisted stalk)
Tephrosia virginiana (goat's rue)
Thalictrum dioicum (early meadow rue)
Thalictrum pubescens (tall meadow rue)
Thalictrum thalictroides (rue anemone)
Tiarella cordifolia (foam flower)
Trientalis borealis ssp. borealis (starflower)
Trillium cernuum (nodding trillium)
Trillium erectum (wakerobin, purple trillium)
Trillium undulatum (painted trillium)
Uvularia grandiflora (bellwort, merrybells)
Uvularia sessilifolia (wildoats, merrybells)
Verbena hastata (blue verbena, blue vervain)
Vernonia noveboracensis (New York ironweed)
Veronicastrum virginicum (Culver's root)
Viola canadensis (Canada violet)
Viola conspersa (American dog violet)
Viola pedata (bird-foot violet)
Viola pubescens (downy or smooth yellow violet)
Viola soraria (common blue violet, meadow violet)

Zizia aptera (heart-leaved golden alexanders)
Zizia aurea (golden alexanders)

Grasses/Grass-like plants

Agrostis scabra (ticklegrass, fly-away grass)
Andropogon gerardii (big bluestem)
Andropogon glomeratus (bushy bluestem)
Andropogon virginicus (broom sedge)
Bromus kalmii (prairie brome, wild chess)
Calamagrostis canadensis (bluejoint grass)
Carex aquatilis (water sedge)
Carex pensylvanica (Pennsylvania sedge)
Carex plantaginea (plantain-leaved sedge)
Carex stipata (awl-fruited sedge)
Carex stricta (tussock sedge)
Carex rostrata var. utriculata (beaked sedge)
Danthonia spicata (poverty grass)
Deschampsia cespitosa (tufted hairgrass)
Distichlis spicata (seashore saltgrass)
Eleocharis palustris (creeping spikesedge, spike rush)
Elymus canadensis (Canada wild rye)
Elymus hystrix var. hystrix (bottlebrush grass)
Eragrostis spectabilis (purple lovegrass, tumblegrass)
Glyceria grandis (American mannagrass, tall mannagrass, reed meadowgrass)
Juncus effusus var. pylaei (soft rush)
Leersia oryzoides (rice cut grass)
Panicum virgatum (switchgrass)
Schizachyrium scoparium (little bluestem)
Scirpus acutus (hardstem bulrush)
Scirpus atrovirens (dark green bulrush)
Scirpus cyperinus (wool grass)
Scirpus tabernaemontani (great bulrush)
Sorghastrum nutans (Indian grass)
Sporobolus asper (dropseed)
Trisetum spicatum (spike trisetum)
Typha latifolia (cattail)

Shrubs (deciduous)

Amelanchier arborea (downy serviceberry, shadbush, Juneberry)
Aronia melanocarpa (black chokeberry)
Ceanothus americanus (New Jersey tea, red root)
Cephalanthus occidentalis (buttonbush)
Clethra alnifolia (summer sweet)
Cornus alternifolia (pogoda dogwood, alternate-leaved dogwood)

Cornus amomum ssp. obliqua (swamp dogwood, silky dogwood)
Cornus foemina ssp. racemosa (gray dogwood)
Corylus americana (American hazelnut or filbert)
Corylus cornuta (beaked hazelnut or filbert)
Diervilla lonicera (bush honeysuckle)
Dirca palustris (leatherwood, ropebark)
Euonymus americana (strawberry bush, brook euonymus, hearts-a-bustin')
Hydrangea arborescens (wild hydrangea)
Ilex verticillata (winterberry, black alder)
Lindera benzoin (spicebush)
Lonicera dioica (limber or wild honeysuckle)
Lyonia ligustrina (male-berry, male-blueberry)
Physocarpus opulifolius (ninebark)
Prunus virginiana (chokecherry)
Rhus aromatica (fragrant sumac)
Rhus copallinum (dwarf or winged sumac)
Rhus glabra (smooth sumac)
Rhus hirta (staghorn sumac)
Ribes cynosbati (prickly gooseberry, dogberry)
Rosa arkansana var. suffulta (prairie rose)
Rosa blanda (early wild rose, smooth rose)
Rosa carolina (Carolina rose)
Rubus idaeus ssp. strigosus (red raspberry)
Rubus occidentalis (black raspberry, thimbleberry)
Rubus odoratus (thimbleberry)
Sambucus canadensis (elderberry, common elder)
Sambucus racemosa var. pubens (scarlet elderberry, red-berried elder)
Spiraea alba (meadow sweet)
Spiraea tomentosa (steeplebush, hardhack)
Staphylea trifolia (bladdernut)
Symphoricarpos albus (snowberry)
Vaccinium angustifolium (low-bush blueberry)
Vaccinium corymbosom (highbush blueberry)
Viburnum acerifolium (maple leaf viburnum)
Viburnum dentatum (southern arrowwood)
Viburnum lentago (black haw, nannyberry)
Viburnum nudum var. cassinoides (wild raisin)
Viburnum opulus var. americanum (high-bush cranberry, American cranberrybush viburnum)
Viburnum prunifolium (black haw, nanny berry)

Shrubs (evergreen)

Ilex glabra (inkberry, bitter gallberry)
Juniperus communis (common juniper)

Trees (deciduous)

Acer pennsylvanicum (striped maple)
Acer rubrum (red maple)
Acer saccharinum (silver maple)
Acer saccharum (sugar maple)
Amelanchier canadensis (shadblow serviceberry, Juneberry)
Betula alleghaniensis (yellow birch)Betula papyrifera (paper birch)
Carpinus caroliniana (blue beech, hornbeam, musclewood)
Carya alba (mockernut hickory)
Carya cordiformis (bitternut, swamp hickory)
Carya ovata (shagbark hickory)
Cornus florida (flowering dogwood)
Crataegus crusgalli (cockspur hawthorn)
Crataegus punctata (dotted hawthorn, white thorn)
Fagus grandifolia var. caroliniana (beech)
Fagus grandifolia (beech)
Fraxinus americana (white ash)
Fraxinus pensylvanica (green ash)
Gymnocladus dioica (Kentucky coffee tree)
Hamamelis virginiana (witch hazel)
Juglans cinerea (butternut, white walnut)
Juglans nigra (black walnut)
Larix laricina (tamarack, American larch)
Liriodendron tulipifera (tulip tree)
Ostrya virginiana (ironwood, hophornbeam)
Platanus occidentalis (sycamore, plane-tree)
Prunus americana (wild plum)
Prunus nigra (Canada plum)
Prunus pensylvanica (fire or pin cherry)
Prunus serotina (black cherry)
Quercus alba (white oak)
Quercus bicolor (swamp white oak)
Quercus coccinea (scarlet oak)
Quercus macrocarpa (bur oak)
Quercus muhlenbergii (chinkapin oak, chestnut oak)
Quercus palustris (pin oak)
Quercus rubra (red oak)
Quercus velutina (black oak)

Trees (evergreen)

Ilex opaca (American holly, Christmas holly)
Juniperus virginiana (eastern red cedar)
Picea glauca (white spruce)

Pinus resinosa (red pine)
Pinus rigida (pitch pine)
Pinus strobus (eastern white pine)
Thuja occidentalis (arbor vitae, northern white cedar)
Tsuga canadensis (eastern hemlock)

Vines (deciduous)

Celastrus scandens (American bittersweet)
Clematis occidentalis (purple clematis)
Clematis virginiana (virgin's bower)
Lonicera sempervirens (coral honeysuckle)
Parthenocissus quinquefolia (Virginia creeper)
Vitis aestivalis (summer grape)
Vitis labrusca (fox grape)
Vitis riparia (riverbank grape)

Appendix 5. Literature Review

Table of Contents

Executive Summary

Methods

Literature sources and search engines from Moon Library at State University of New York (SUNY) College of Environmental Science and Forestry and Cornell University were used in the literature survey. On-line resources such as Google Scholar were also used to obtain references on slopes failures and vegetation management of landslides.

General Findings

Most literature pertinent to the Irondequoit Bay was descriptive in nature, particularly in regards to slope failures. A number of studies have documented the extent and history of slope failures on the Bay. Information on vegetation characteristics and management for the Bay was scarce. Considerably more information was available for bluff and shore recession, vegetation and management for the southern shore of Lake Ontario, and the other Great Lakes.

A large volume of literature and research were found on the impact of vegetation on slope stability, although most of it was not specific to the Irondequoit Bay. However, this literature solidly documents the positive impacts of vegetation on slope stability. A substantial amount of literature was also found on the use of vegetation to stabilize slopes.

Soils and Vegetation

There is little specific information on the vegetation of the Bay's slopes, although most reports indicate that slopes have always been primarily wooded. White settlement of the area began about 1800 with clearance of forests for farms. Clear cutting was done between 1850 and 1900 and accordingly, tree growth on the Bay's hillsides is believed to be mostly second generation. Vegetation currently was cited as being comprised of "transition hardwoods", including oak, poplar, and hickory.

Soils on the Bay's slopes are of the Arkport-Collomer association and are primarily of the Arkport series, but Arkport, Dunkirk and Colonie soils or a combination of these soils may occur on the steep slopes. The surface soils have mostly been eroded, and where they exist they are silt loam to loamy, fine sand. The steep slopes make all these soils highly susceptible to erosion especially when vegetation is removed.

Slope Failures

Slope failures on Irondequoit Bay are a natural process that has been accelerated by man's activities. In their natural state, slopes on the Bay are heavily wooded. Disturbance of the slopes by removing vegetation, construction and disturbance of the non-cohesive soils, and altering groundwater levels have contributed to slope failures. Natural events such as periods of excessive rainfall, wave action on toe slopes, and wind and water surface erosion, are also factors. Drainage and precipitation, as they affect groundwater levels are likely the most important cause of mass movement or landslides on the Bay.

Studies using aerial photographs showed that most slope failures are on the east side of the Bay. Only two significant slope failures were recorded through 1989 on the west side of the Bay. Slope failures on the Bay represent mass movements, where there is mass downward and outward moving of slope forming materials. Slide materials on the Bay are mostly non-cohesive sand, silt and clay. In comparison, erosion is a surface oriented loss of soil through detachment and transportation of soil particles by wind, water, and other natural forces.

Impacts of Vegetation

Removal of trees and other vegetation have been documented in other ecosystems as an important factor contributing to slope failures. Dose response relationships, where increasing landslide occurrence and intensity have occurred in response increased disturbance in vegetation, have also been documented.

While grass and herbaceous cover are extremely effective in reducing surface erosion, woody shrubs and trees are most effective in stabilizing slopes against mass movement. Woody vegetation reduces the potential for mass movement by a number of well-documented mechanisms. These include mechanical re-enforcement of soil by roots, soil moisture depletion by interception and evapotranspiration, soil buttressing and arching from stems, and soil surcharge. Several potential negative effects of trees were found, but the positive effect of trees on slope stability clearly outweighs any negative impacts.

Use of Vegetation for Slope Stabilization

The use of vegetation, in combination with engineering or mechanical practices to stabilize or prevent slope failures, is known as biotechnical slope protection. This combined use of engineering approaches and vegetation is usually more beneficial than engaging in either approach autonomously. Biotechnical slope stabilization is most effective against shallow mass movement of slopes, and is unlikely to be effective where deep-seated factors are the cause of deep-seated slope failures. Many different biotechnical approaches have been defined and used, but a complete understanding of the site and cause of any slope failure is critical before any treatment is defined.

Use and preservation of native vegetation to stabilize slopes has many attractive features. Native vegetation is adapted to local soils and climate, and can form natural communities similar to what is already present in an area. Since the Irondequoit Bay is a valuable and important landscape in Monroe County, preservation of this ecosystem by the use of native vegetation and biotechnical engineering may have the potential to stabilize slopes while maintaining the aesthetics and ecology of the area.

Introduction

This document presents the results of a review of prevalent literature pertinent to current slope and vegetation management practices being employed on the Great Lakes and other similar ecosystems. It is the first in a series of three sequential tasks to be completed as part of a proposal to investigate the importance of vegetation in slope failures in the Town of Irondequoit. Task 2 will collect data via field survey of the slopes to classify their stability, vegetation characteristics, and to determine their current management needs. Task 3 is to develop a vegetation management plan for the slopes based on the information collected in the literature review and field survey of slopes in the Town along Irondequoit Bay.

The eastern edge of the Town of Irondequoit borders the Irondequoit Bay of Lake Ontario. This border includes a series of steep slopes with some that drop sharply to the shores of the Bay. The slopes in the Town are inherently fragile, and given their steepness, non-cohesive soils, and sensitivity to disturbance, are potentially unstable. Vegetation on the slopes varies from climax oak/maple to pioneer species invading disturbed soils.

Residential homes have been constructed on the top and bottom of some of the slopes, and there is continued pressure for additional development. There have been recent slope failures as a direct result of construction and other activities of private landowners. These failures represent a significant risk to nearby properties, contribute to environmental degradation of the bay and lake, and are a financial burden to the Town.

Private land owners are also frequently uninformed regarding the Town Code and other New York State Department of Conservation (DEC) regulations governing activities on these slopes, and the possible consequences of their actions. Tree service contractors are also often unaware of the potential impact of working on the slopes and may prune or remove trees at the request of the property owners. Consequently, the removal of vegetation on these slopes has been and may continue to be an important contributing cause of slope failures.

Despite the Town Codes and DEC regulations governing the management of the slopes, additional proactive planning is needed to maintain stable slopes along the Irondequoit Bay. Development of a comprehensive approach for vegetation and slope management will help prevent the likelihood of additional failures in the future.

Methods

Literature sources and search engines from Moon Library at State University of New York (SUNY) College of Environmental Science and Forestry, Syracuse and Cornell University were used in the literature survey. On-line resources such as

Google Scholar were also used to obtain references on slopes failures and vegetation management of landslides.

In addition to traditional literature searching, personal contact to locate local sources of information and knowledge were made with personnel or researchers at the University of Rochester, SUNY at Geneseo, SUNY Environmental Science and Forestry, New York State Department of Environmental Conservation, extension at the Cornell University Extension Sea Grant Institute in Brockport, and at the Monroe County Soil and Water Conservation.

Slope failures and stabilization is worldwide issue and there is a large amount of available literature from which to select. However, this review focused on literature with the following emphasis: vegetation impacts and slope failure information that were specific to the Irondequoit Bay, Lake Ontario, the Great Lakes, as well as studies and information from ecosystems in other areas of the United States, Canada and elsewhere.

Literature Review

General Findings

Most literature pertinent to the Irondequoit Bay was descriptive in nature, particularly in regard to slope failures. A number of studies have documented the extent and history of slope failures on the Bay. Information on vegetation characteristics and management for the Bay was scarce. Monroe County Soil and Water Conservation Service provide advice on vegetation planting and management based on their experience with the site. Considerably more information was available for bluff and shore recession, management and vegetation for the southern shore of Lake Ontario and the other Great Lakes.

Outside the Great Lakes ecosystem, a substantial body of literature was found on factors affecting slope stability and failures, vegetation impacts on slopes, and management of vegetation to mitigate slope erosion and landslides. This literature should be applicable to the Irondequoit Bay as significant emphasis was placed on evaluation of the causes of slope failures when determining management approaches. Clearly, an understanding of the root causes of slope failures on the Irondequoit Bay will be needed in order to determine if vegetation management, or combined vegetation and engineering practices can be used to achieve long-term slope stability.

Characteristics and History of the Irondequoit Bay

Location and Physical Geography

Characteristics and history of the Irondequoit Bay are reviewed here only as they are important to slope failures and vegetation management. The Bay is a lake that is 6.7 km long and 1km wide and is bound on its north end by a sandbar

(Bannister and Bubeck, 1978). Virtually all of the west side of the Bay lies within the Town of Irondequoit.

The Irondequoit creek is its principal tributary and enters at the Bay's south end. The Bay is bounded by steep wooded slopes on both its east and west sides, and together, with the water resource, is regarded as an "extraordinary valuable asset of the community" (Bannister and Bubeck, 1978). The Irondequoit Bay Technical Committee identifies steep slopes as any slope greater than 15% (15 feet vertical rise to 100 feet horizontal distance), and most slopes along the Bay are 30% to 120% with some locations having slopes greater than 120% (Wang, 1990). About 40% of the Bay's perimeter is marked by steep slopes which rise 30 to 45 m over horizontal distances of 0.2 to 0.5 km. In some locations, the shoreline has nearly vertical silt bluffs that are up to 15 m high which are bare of vegetation (Bannister and Bubeck, 1978). However, these are more common on the east side of the bay (Wang, 1990).

The proximity of the bay 6 km to the north of the City of Rochester makes it an attractive location for development and recreation. Recent strides in water treatment have greatly increased the quality of water in the Bay (Bannister and Bubeck, 1978). To this day, public planning has had to deal with development and "reconciling heavy public use with maintenance of woodlands and stabilization of the hillsides" (Bannister and Bubeck, 1978; Wang, 1990).

Geology

The geology of the Irondequoit Bay has been extensively studied and documented. The geology of the Bay is dominated by glacial drifts deposited on sedimentary strata (Bannister and Bubeck, 1978). The bay formed when glacial fill blocked the Genesee River, thus changing its course and leaving a valley. Elevation of the St. Lawrence region filled Lake Ontario with fresh water, and the Irondequoit Bay formed in the old Genesee river valley when it was separated from Lake Ontario by a sandbar on its northern edge (Bannister and Bubeck, 1978).

Soils (Adapted from Soil Survey of Monroe County, (Heffner and Goodman, 1973))

Soils on the slope along the bay are of the Arkport-Collomer association and are primarily of the Arkport series, but Arkport, Dunkirk and Colonie soils or a combination of these soils may occur on the steep, 20 to 60 percent slopes. The surface soils have mostly been eroded. However, where they do exist, they are silt loam to loamy, fine sand. The steep slopes make all these soils highly susceptible to erosion, especially when vegetation is removed. The unstable, non-cohesive sand and silt present in these soils may impact many engineering uses.

Arkport series soils are reported to make up about half the soils on the slopes, and are deep, well-drained and medium textured. Upper layers are comprised of

very fine sandy loam, with neutral pH and high permeability. Lower layers are loamy very fine sand and very fine sandy loam with bands of clay. The substratum is at a depth of 44 inches and is calcareous loamy fine sand with bands of very fine sandy loam. Depth of the soil for rooting is at least 30 inches, and available water capacity is moderate. Erosion and soil blowing are problems on exposed soil.

Colonie soils are acid, deep, well-drained to excessively drained, course-textured soils, which are comprised of loamy fine sand through the B layer and fine sand in the C layers. The depth of soil for rooting is mainly in the upper 30 inches, although there is little restriction to deeper rooting. Available water capacity is low to a depth of 24 inches, and lack of moisture during the growing season can hamper plant establishment. Wind erosion of exposed soil can be a problem with Colonie soils.

Dunkirk series soils are deep, well-drained and are medium to moderately fine textured. Surface soils are acid, silt loams, and lower soil depths are silt loams, and silty clay loams. The lowest strata are banded layers of clay and silt. The depth of soil available for rooting is 30 to 36 inches, and available water capacity is high. Lower strata of Dunkirk soils are calcareous. These soils are suggested to be the most erodible in Monroe County and, erosion control is needed even on gentle slopes.

The soil survey of Monroe County suggests that where these soils are in their natural state, they should remain undisturbed, and if vegetative cover is removed it should be restored. Because of their texture and severe slope, these soils are poorly suited for virtually all uses including sanitary landfill, underground public utilities, disposal of septic tank effluent, home sites, streets and parking, picnic and play areas, athletic fields, campsites, hiking and riding trails, and lawn or turf uses.

Vegetation

There is little specific information on the vegetation on the slopes, although most reports indicate that slopes have always been primarily wooded (Bannister and Bubeck, 1978). White settlement of the area began about 1800 with clearance of forests for farms, and this commenced a long period of deterioration of the water quality in the Bay. Clear cutting was performed between 1850 and 1900 (Wang, 1990) and accordingly, tree growth on the hillsides is believed to be mostly second generation. Wang (1990), citing personal communication with the New York State Department of Environmental Conservation, indicated that area is comprised of “transition hardwoods”, including oak, poplar, and hickory. Chestnut blight was subsequently introduced in the early 1900’s and likely wiped out the American chestnut as a dominant species in the area, which, in turn, allowed oak species to increase in abundance (Wang, 1990).

Information from the soil survey of Monroe County indicates that sugar maple is an indicator species for the Arkport-Collamer, and that white pine and larch are acceptable for planting. Mixed stands of sugar maple, white pine, red oak, black cherry, basswood, white ash, black walnut, black walnut, red pine, and hemlock develop on these soils.

The steep Arkport soils are listed as unsuited for grasses and legumes, but well suited for wild herbaceous and upland plants, hardwoods, conifers, and woodland plantings. Colonie soils are listed as generally unsuited for even woodlands, and Dunkirk soils are similar to Arkport soils except they are better suited for grasses and legumes.

Slope Failures on Irondequoit Bay

History of Slope Failures

Using aerial photography, Wang (1990) documented that more than 1/3 of landslides on the east side of the bay had already developed by 1930. Landslide number and size was found to be significantly less on the west side, or Town of Irondequoit side, of the Bay. Only two landslides of significance on the west side were noted by Wang (1990), one at Snider Island and one that occurred in 1974 after a heavy rain south of Ides Cove (Summa, 1979).

However, Wang (1990) observed that down-slope portions of Point Pleasant Rd. and Seneca Rd. on northwest side of the Bay contained areas with disturbed road fences and tilted trees, which are suggestive of slope movement or creep. The slope around Ides Cove was also noted to be fairly steep and some trees were showing down-slope tilting. In the southwest section, the bay has a wider shore zone, and most of the steep slopes were noted to be further back away from the water (Wang, 1990). No landslide activity was noted except for Snider Island (Wang, 1990).

Public interest in slope failures appeared to escalate in the early 1970's (Bannister and Bubeck, 1978). During that period, high water levels in Lake Ontario, and impacts from Hurricane Agnes caused shoreline erosion, undercutting, and slumping of silt bluffs, as well as heavy sedimentation loading from streams (Bannister and Bubeck, 1978).

Types of Slope Failures

Twin problems of erosion and mass movement on slopes are widespread and costly but have different etiology (Gray and Liester, 1978). Erosion is the removal or detachment and transport of surface layers of soil by wind, water, and ice (Gray and Leister 1989; Sotir and Gray, 1996). Mass movement is downward and outward moving of slope forming materials (Gray and Leister 1989; Sotir and Gray, 1996). Mass movement or landslides, cause the most significance large-scale damage to the slopes on the Bay (Wang, 1990). Mass movements have been classified into six main groups, including falls, topples, slides, spreads,

flows, and complex slope movements involving multiple classifications (Varnes, 1978). Mass movement may involve rock and soil, soil being further divided into debris and earth (Varnes, 1978).

The most common types of mass movement in the Irondequoit Bay are falls, rotational and translation slides, and flows (Wang, 1990). Complex slides, which involve more than one type of mass movement, were also reported (Wang, 1990). Most slide material on slopes of the Irondequoit Bay consisted of unconsolidated sand, silt and clay (Wang, 1990).

Falls
Falls involve the rapid free falling of material detached from a steep slope or cliff along a surface on which little or no shear displacement exists, and the material descends by air or free falling, leaping, bounding, or rolling (Varnes, 1978). Earth falls are the most common type of fall at the Irondequoit Bay, and these were found to be distributed mainly in the southeast section along the steep bluffs (Wang, 1990).

Slides
Slides occur when movement occurs along one or several surfaces that can be viewed or inferred within a relatively narrow zone (Varnes, 1978). Slides are mass movement in which a clearly defined shear surface separates the un-deformed moving mass from the material below, and the velocity of movement remains constant throughout the moving mass (Carson and Kirby, 1972). Slide movement may be progressive and propagate from an area of local failure. Earth slides were reported to be widely distributed along the Bay as were areas that had failed multiple times (Wang, 1990).

Two primary types of slides have been classified, rotational slides, or slumps, and translational slides. Rotational slides occur along a surface that is curved concavely upward (Varnes, 1978). The scarp at the head of a slump may almost be vertical, and if left unsupported, the stage is set for a new failure (Varnes, 1978). Translational slides have little rotary movement, and movement occurs along a planar or gently undulating surface of the rupture (Varnes, 1978). Translational slides are commonly controlled by surface weaknesses such as faults, joints, or bedding planes. In many translational slides, the slide mass is greatly deformed or breaks into many independent units.

Flows
Flows occur when mass movement occurs as a viscous mass, and may involve wet or dry soil, rocks or debris. Shear or slip surfaces in flows are usually not found and the surface of the flow has an undulating surface (Varnes, 1978) which has no sharply defined failure surface (Carson and Kirby, 1972). Velocity of movement is greatest at the top and minimal at the base of the flow. Most flows in the Irondequoit Bay are earth flows and were reported to be distributed in the northeast section (Wang, 1990).

Creep
Creep is the slow down-slope mass movement at the rate of millimeters to centimeters per year (Wang, 1990), although Varnes (1978) suggested avoiding the use of the term. Creep can be observed by the down-slope tilting of fences and telephone poles, deformed road curbs, and curved tree trunks present on some slopes of the Bay (Wang, 1990).

Causes of Slope Failures
Gravity is the most important cause of slope failures. When the shear strength along the surface becomes nearly equal to shear forces promoting a slide, slope failure becomes imminent (Bache, and MacAskill, 1984). Steepness of the slope is a measure of its susceptibility to mass failure (Gray and Liester, 1989). Soils comprised of non-cohesive materials such as sands, which are common on Bay slopes, reduce soil shear strength (Varnes,1978) and increase the likelihood of slides. For example, the presence of non-cohesive soils such as sand or clay-silt on steep slopes contributed to the highest recession rates on the southern shore of Lake Ontario (Brennan and Calkin, 1984; Drexhage and Calkin, 1981).

Besides gravity, precipitation and drainage as they affect groundwater is the next most important factor affecting slides (Bache and MacAskill,1984; Buckler and Winters, 1983; Gray and Leister, 1989; Lieberman and O'Neill, 1988; O'Neil, 1985; Smith and Vanbuskirk, 2002; Zaruba and Mencl, 1982). Even when slopes are stable under normal conditions, excess groundwater can greatly increase the potential for failure (O'Neil, 1985). Rainfall is generally accepted as one of the chief factors controlling the frequency of landslides and measurements have confirmed that recurrent slope movements occur during periods of exceptionally high rainfall (Zaruba and Mencl, 1982).

The depth of the soil piezometric or potentiometric surface (the level to which water rises in a tightly cased well constructed in a confined aquifer) is one of the most important factors influencing the stability of a steep mountain slopes that were mantled with shallow, non-cohesive soils (Gray and Megahan, 1981). Deforestations main impact is an adverse effect on the water regime in subsurface layers (Gray and Liester, 1989; Gray and Megahan, 1981; Zaruba and Mencl, 1982). Human activities that increase groundwater also have direct impacts on slopes failures (O'Neil, 1985).

The presence of sand, silt and clay lenses or layers on Bay slopes may create avenues or barriers to groundwater movement and contribute to slides by increasing pieziometric pressure and lubricating soils (O'Neil, 1985). These layers may be evidence by areas of water seepage on exposed slope soils, or changes in vegetation in response to increased soil moisture (Lieberman and O'Neill, 1988; O'Neil, 1985;). Rib and Liang (1978) and others (Gray and Liester,

1989) have suggested that vegetation changes in response to moisture on slopes may be diagnostic for slope failure potential.

Many other factors may also contribute to slope failures on bay and lake bluffs, including high water levels, wave action that undermines shore banks, bluff orientation, bluff face angle and height, removal of vegetation, and soil disturbances (Brennan and Calkin, 1984; Drexhage and Calkin, 198; Lieberman and O'Neil, 1988; O'Neil, 1985). Bluff recession rates have been well studied on Lake Ontario and other Great Lakes, although recession rates following slope failures on the Irondequoit Bay have not been quantified.

Importance and Impact of Vegetation to Slope Failures
The importance of vegetation for slope stability has been studied across many ecosystems, soil types, and approaches to management. From this work, it is generally recognized that removal of vegetation on steep slopes increases their potential for erosion and landslides (Bishop and Stevens, 1964; Gray and Leister, 1989; Gray and Megahan, 1981; Lewis, 2000; Sotir and Gray, 1989; Swanson and Dyrness,1975). Further, disturbance of vegetation, through logging, road building, creation of trails, brush removal, narrow pathways or through natural events such as fires or excessive precipitation, can contribute or initiate failure of steep slopes (Bache and MacAskill, 1984; Gray and Megahan, 1981; Gray and Leister, 1989; LIberman and O'Neil, 1988).

One way to assess impact of vegetation is to look at the impact of its removal (Gray and Megahan, 1981). Landslide hazard has been observed to increase in direct proportion to the amount of vegetation that was removed (Gray and Megahan, 1981). Forest cover is effective in reducing landslides (Bache and MacAskill, 1984), and increased removal of tree cover increased slide occurrence (Gray and Megahan, 1981). Variation in the age and species of forest vegetation can also affect the local stability of forest slopes, with mature forest providing more root stabilization then planted forests (Schmidt et. al., 2001).

Grasses and herbaceous plants are well known in preventing surface erosion and have been used extensively for this purpose (Gray and Leister, 1989; Bache and MacAskill, 1984; Sotir and Gray; 1996; Schiechtle, H. M. 1985). While grasses and herbaceous plants are most effective in reducing erosion, woody vegetation is the most effective in preventing mass-movement (Bache and MacAskill, 1984; Gray, 1995; Gray and Leister, 1989 Lewis, 2000; Sotir and Gray, 1996;).

Woody vegetation is most effective in reducing shallow sliding in slopes (Gray, 1995; Gray and Leister, 1989; Lewis, 2000; Sotir and Gray, 1996). Woody vegetation has both positive and negative influences on slope stability and mass movement. However, the overall impact of vegetation on slope stability is

overwhelmingly positive (Bache and MacAskill, 1984; Gray, 1995; Gray and Leister, 1989; Lewis 2000; Sotir and Gray, 1996),

Mechanical reinforcement from root systems

Roots have been shown to mechanically reinforce soil by transfer of shear stresses in the soil to tensile resistance in the roots (Bache and MacAskill, 1984;; Gray and Leister, 1989; Schmidt et al. 2001; Wu et. al., 2004). Roots also bind the soil and increase its shear strength, and higher root concentrations and roots with the high tensile strength are the most efficient (Bache and MacAskill, 1984). Root size, depth, and morphology are important, with soil-rooting strength being favored by high concentration of long, flexible roots per unit volume, and a high tensile strength in roots (Wu et al., 2004). Deep-rooted species with vertical and tap roots are most effective for stabilizing and resisting sliding on slopes (Gray and Leister, 1989; Gray and Megahan, 1981).

Stumps and roots of felled trees are valuable in stabilizing slopes (Gray and Leister, 1989; Gray and Megahan 1981). The effectiveness of dead root systems decreases with time as the roots decay (Gray and Liester, 1989; Gray and Megahan, 1981; Schmidt et. al., 2001). Lieberman and O'Neill (1988) suggested that trees on the edge of bluff faces that are likely to fail should be removed before their catastrophic failures increases damage to the slope.

Soil moisture modification

Woody vegetation reduces soil moisture reaching the soil surface through interception, and vegetation removes large amounts of water from the soil through evapotranspiration. Drying of the soil profile or reduction of soil moisture reduces pore water pressure, reduces the unit weight of soil, enhances soil cohesion (Bache and MacAskill, 1984; Gray and Leister, 1989; Gray and Megahan, 1981; Sotir and Gray, 1996) and affects the water regime in subsurface layers (Zaruba and Mencl, 1982).

Buttressing and arching

Tree stems and buttress roots that are firmly anchored can act as "piles" or "abutments" on a slope that help reduce soil shearing. Soil arching occurs when soil begins to move through and around trees embedded or anchored in an unyielding layer (Gray and Megahan, 1981). Greater stems densities increase this effect. The minimum effective spacing between trees on an Idaho Batholith was found to be 30 feet (Gray and Megahan, 1981).

Slope surcharge from the weight of trees

Trees exert a down slope stress on a slope that may destabilize it. A second force perpendicular to the slope aids in increasing resistance to sliding (Gray and Megahan, 1981). Slope surcharge helps stabilize slopes or may contribute to slope failures (Gray and Leister, 1989) when slopes begin to fail.

Wind-throw

Wind-throw, or the overturning of trees in high wind events, creates localized disturbances in the soil mantle (Gray and Leister, 1989). Wind throw is most common in older, mature trees particularly those with diseased or decayed root systems. Wind leveraging is the loosening of soils when forces on the trunk are conveyed into the root system and soil (Mattheck and Broeler, 1994).

Root Wedging

Root wedging is the tendency of roots to penetrate soil, or cracks in rock masses and thereby loosening it and opening cracks or channels (Bache and MacAskill, 1984; Gray and Leister, 1989;). This supposed mechanism of increasing soil instability has not been well documented or substantiated (Gray and Leister, 1989).

Management of Vegetation to Reduce Slope Failures

Preservation of Vegetation

Woody-deep rooted trees and shrubs are the best vegetation to provide slope stability, and the removal of vegetation from forested slopes increases landslides (Dhakal and Sidle, 2003). To the extent that woody vegetation can stabilize slopes, its removal can trigger increase slope failures (Gray and Leister, 1989; Rickson and Morgan, 1995). Even the temporary loss of foliage can be significant due to reductions in interception and transpiration that lead to wetter conditions and higher slope piezometric levels (Gray and Leister, 1989). Vigorous under-story vegetation was also found to be effective in reducing landslide volumes (Dhakal and Sidle, 2003). To that extent, preservation of woody vegetation on steep slopes will prevent some but not all slope failures, as some failures also occur via natural processes (Gray and Leister, 1989).

Vegetation management outside the perimeter of a slope is important in managing local hydrology (Marui, 1988). Preservation and establishment of trees on plateaus above steep slopes will perform similar functions in reducing ground water soil moisture and erosion, as vegetation does on the slopes themselves (Lierberman and O'Neill, 1988; Marui, 1988). The common practice of disposing grass clippings and leaves over the edges of banks on steep slopes should be avoided, as it prevents the development of vegetated ground cover and understory plants (Lieberman and O'Neill, 1988).

Aside from timber harvesting or logging, active forestry practices to manage growth of trees on slopes to reduce landslides per se has not been extensively investigated. Evidence from the literature suggests that practices that favor increased canopy cover from both over-story and under-story will be important (Gray and Megahan, 1981; Hallin, 1967). Establishing of increasing canopy cover will increase interception and evapotranspiration (Gray and Leister, 1989). Planting and management should favor deep rooted tree species and high stem

densities from mature trees (Dhakal and Sidle, 2003; Roering et al., 2003; Schmidt et. al., 2001), if possible.

Invasion of disturbed soils on Bay slopes by Norway maple, ailanthus, and other non-native pioneer species is likely detrimental to long-term slope stability, although this appears to not been directly studied. Norway maple is considered detrimental to most native ecosystems because it has ecophysiological advantages over native species such as sugar maple (Kloeppl and Abrams, 1995). It aggressively spreads and reproduces into disturbed soils (Bertin et al., 2005). Furthermore, Norway maple's dense shade suppresses native plant diversity (Wyacoff and Webb, 1999) and reduces density of desirable native tree species such as white ash, red oak, black locust (Bertin et. al. 2005) and sugar maple (Kloeppl and Abrams, 1995).

Re-Establishment of Vegetation

The risk of erosion and slope failure increases as vegetation is removed. However, the important question is: can the situation be repaired if vegetation is restored (Rickson and Morgan, 1995)? Vegetation was suggested to be of little value in stopping deep-seated stability issues such as rotational slides (Gray and Leister, 1989), and these were suggested to require construction methods (Bache and MacAskill, 1984). A slope ratio of 1 :1.5 was suggested to be the dividing line between a slope that is manageable with vegetation alone and one that establishment of vegetation would be impossible (Lieberman and O'Neal, 1988).

Between deep-seated stability problems and surface phenomena (erosion), there exists a regime in which combined vegetative-structural measures may provide an attractive method of combating erosion and slope failures (Bache and MacAskill, 1984). A biotechnical approach may be an alternative for excessively steep slopes if deep-seated stability issues are not present. Biotechnical approaches use vegetation and structural or engineering components (Bache and MacAskill, 1984; Gray and Leister, 1989). Both elements must function together in an integrated and complimentary manner (Gray and Leister, 1989).

Bioengineering has a number of advantages over the sole use of mechanical approaches. It can be used on steep slopes that are inaccessible to heavy equipment. Bioengineered systems become more stable with time as plants grow. They can be installed during dormant seasons, and they improve landscape and habitat values (Lewis, 2000; Sotir and Gray, 1996).

Bioengineering has gained considerable attention as experience has been gained with its practices (Lewis, 2000; Sotir and Gray, 1996; Rickson and Morgan, 1995). Soil bioengineering is cited as a specialized form of biotechnical engineering because roots and stems of the plants themselves provide the mechanical element that stabilizes the soil, such that native vegetation can eventually take over and provide stabilization (Sotir and Gray, 1996).

Biotechnical slope protection systems may be more cost effective than the use of either vegetation or structures alone (Lewis, 2000). Vegetation alone is the least expensive method of slope protection, but it may be less effective under severe conditions (Gray and Leister, 1989). Bioengineering solutions should be regarded as capitalizing on the benefits of vegetation while minimizing its weaknesses (Sotir and Gray, 1996).

In mixed mechanical and vegetation construction, vegetation provides definitive contributions to the stabilization process (Bache and MacAskill, 1984; Gray and Leister, 1989; Lewis, 2000; Sotir and Gray, 1996;) including:

- Binding and restraining of soil particles
- Interception of raindrops
- Filtering soil in runoff
- Soil reinforcement
- Soil buttressing
- Soil arching
- Depleting of soil moisture

A number of publications have outlined the vegetative, structural-mechanical, and structural-vegetative components that can be used together with vegetation to stabilize slopes (Abramson, 2001; Bache and MacAskill, 1984; Gray and Leister, 1989;; Lewis, 2000; Lieberman and O'Neil, 1988; Marui, 1988; O'Neil, 1985; Schiechtle, 1985; Sotir and Gray, 1996). Virtually all these resources place an emphasis a thorough understanding of the slope and site is required by conducting a slope stability analysis. Slope stability analysis attempts to understand the critical geological, material, environmental and economic factors, as well as the nature, magnitude, and frequency of the slope issue (Sotir and Gray, 1996).

It is unlikely that biotechnical and engineering practices will be successful without management of drainage and other factors contributing to the Bay's slope failures. Most sources indicate that slope stabilization cannot be successful without drainage measures that prevent water reaching the slope and remove water already in the slope (Bache and MacAskill, 1984; Gray and Leister, 1989, Gray and Megahan, 1981;Lieberman and O'Neill, 1988; O'Neill, 1985). Clearly, management of drainage and precipitation as it affects groundwater is key (Gray and Leister, 1989). Management of vegetation on the slopes is an important but not primary factor in preventing slope failures.

Selection of Vegetation for Slope Stabilization

Native vegetation is often an excellent indicator of the types of plant communities that will ultimately prevail on a site, and creation of self sustaining communities is an important ecological goal (Bache and MacAskill, 1984). Another goal is to maintain natural conditions as near as possible (Clark 1977; Johnson, 1989; Lieberman and O'Neal, 1988). Use of native plant material and seed may save

money, and indigenous plants are usually readily available and well adapted to local climate and soil conditions (Lewis, 2000).

The right selection and spacing of vegetation is critical. Dense grasses and herbaceous materials are important for managing surface erosion, while deep rooted shrubs and trees are more effective for stabilizing shallow, mass-movement (Gray, 1995; Sotir and Gray, 1996; Lewis, 2000; Schiechtle, H. M. 1985; Bache and MacAskill, 1984). Grasses and herbaceous plants are used to quickly establish ground cover and reduce surface erosion, while planting of trees and under-story, woody vegetation aims to increase long-term slope stability (Bache and MacAskill, 1984; Gray, 1995; Lewis, 2000; Schiechtle, 1985; Sotir and Gray, 1996).

Careful consideration should be given to the characteristics of the vegetation selected, as root architecture of woody plants greatly influences their ability to reduce soil shear (Wu et. al., 2004). Plants used in biotechnical approaches must be adapted to local soils and conditions (Lieberman and O'Neill, 1988; Sotir and Gray, 1996). Attention must be given to spacing amongst stems, as this significantly affects slope stability (Dhakal and Sidle, 2003; Roering et al., 2003; Schmidt et al., 2001). A number of lists of plants suitable for slopes in this area (Lieberman and O'Neill, 1988) and characteristics of plants suitable for slopes have been developed (Sotir and Gray, 1996).

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